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(71) Applicant (for all designated States except US): **THE SECRETARY OF STATE FOR DEFENCE** [GB/GB]; Defence Evaluation Research Agency, A4 Building, Ively Road, Farnborough, Hampshire GU14 0LX (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **GOODBY, John, William** [GB/GB]; School of Chemistry, University of

Hull, Hull HU6 7RX (GB). **TOYNE, Kenneth, Johnson** [GB/GB]; School of Chemistry, University of Hull, Hull HU6 7RX (GB). **HIRD, Michael** [GB/GB]; School of Chemistry, University of Hull, Hull HU6 7RX (GB). **FRIEDMAN, Mark, Richard** [GB/GB]; School of Chemistry, University of Hull, Hull HU6 7RX (GB). **JONES, John, Clifford** [GB/GB]; DERA Malvern, St. Andrews Road, Malvern, Worcs WR14 3PS (GB).

(74) Agent: **BOWDERY, A., O.**; D/IPD, DERA Formalities, A4 Building, Ively Road, Farnborough, Hampshire GU14 0LX (GB).

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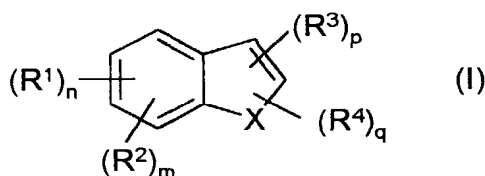
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(54) Title: LIQUID CRYSTAL COMPOUNDS



(57) Abstract: A liquid crystal compound of general formula (I) where X is O, S or Se, and R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, m, n, p and q are as specified in the application. Liquid crystal devices comprising said compounds are also claimed.



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## LIQUID CRYSTAL COMPOUNDS

The present invention relates to novel compounds having a fused heterocyclic ring which have the properties of liquid crystals, together with processes for their preparation and liquid crystal devices incorporating them.

5       The term "liquid crystals" is well known. It refers to compounds which, as a result of their structure, will align themselves in a similar orientation, preferably at working temperatures, for example of from  $-40$  to  $200^{\circ}\text{C}$ . These materials are useful in various devices, in particular the liquid crystal display devices or LCDs.

10       Liquid crystals can exist in various phases. In essence there are three different classes of liquid crystalline material, each possessing a characteristic molecular arrangement. These classes are nematic, chiral nematic (cholesteric) and smectic.

Broadly speaking, the molecules of nematic compounds will align themselves in a particular orientation in a bulk material. Smectic materials, in addition to being orientated in a similar way, will align themselves closely in layers.

15       A wide range of smectic phases exists, for example smectic A and smectic C. In the former, the molecules are aligned perpendicularly to a base or support, whilst in the latter, molecules may be inclined to the support. Some liquid crystal materials possess a number of liquid crystal phases on varying the temperature. Others have just one phase. For example, a liquid crystal material may show the following phases on being cooled  
20       from the isotropic phase: - isotropic - nematic - smectic A - smectic C - solid. If a material is described as being smectic A then it means that the material possesses a smectic A phase over a useful working temperature range.

25       Such materials are useful, in particular in display devices where their ability to align themselves and to change their alignment under the influence of voltage, is used to impact on the path of polarised light, thus giving rise to liquid crystal displays. These are widely used in devices such as watches, calculators, display boards or hoardings, computer screens, in particular laptop computer screens etc. The properties of the compounds which impact on the speed with which the compounds respond to voltage charges include molecule size, viscosity ( $\Delta n$ ), dipole moments ( $\Delta \epsilon$ ), conductivity etc.

30       Some examples of bicyclic liquid crystal compounds are found in DE-A-19900517 and WO 98/04544.

The applicants have found a new class of chemicals that have useful liquid crystal properties. In particular the invention provides a liquid crystal compound

having a fused five and six-membered ring, at least one of said rings containing a heteroatom, and at least one of said rings carrying a substituent. Preferably, each ring has at least one substituent.

Suitable heteroatoms for use in the ring system of the invention include  
5 oxygen, sulphur, nitrogen and selenium. Where nitrogen is present, it may carry a hydrogen or a substituent group, depending upon the nature and the aromaticity of the ring system.

The ring system may be aromatic or non-aromatic, but is preferably aromatic.

Specific examples of the ring system of the invention include benzofurans and  
10 benzopyrans.

The nature of the substituents on the ring will determine the particular liquid crystal properties of the compound. Large substituents will tend to increase the viscosity of the compound, thereby increasing the time taken for the molecules to adopt the appropriate orientation under the influence of a voltage. The number of free  
15 electrons which are contained within the substituents influences optical properties of the compound. Aromatic rings will have relatively high conductivity whereas strongly electronegative groups such as cyano, will tend to reduce conductivity.

The nature of the substituents on the ring can therefore be selected so as to impart the desired liquid crystal properties on the final compound. For example, some  
20 applications as outlined below require chiral molecules. For this purpose, the compounds of the invention suitably contain an asymmetric centre.

Typical substituents will comprise a functional group, optionally substituted hydrocarbyl, optionally substituted alkoxy, optionally substituted heterocyclyl or carboxy or a hydrocarbyl ester or amide thereof.

25 As used herein, the term "hydrocarbyl" refers to any structure comprising carbon and hydrogen atoms. For example, these may be alkyl, alkenyl, alkynyl, aryl such as phenyl or naphthyl, arylalkyl, cycloalkyl, cycloalkenyl or cycloalkynyl. Suitably they will contain up to 20 and preferably up to 10 carbon atoms. The term "heterocyclyl" includes aromatic or non-aromatic rings, for example containing from 4  
30 to 20, suitably from 5 to 10 ring atoms, at least one of which is a heteroatom such as oxygen, sulphur or nitrogen. Examples of such groups include furyl, thienyl, pyrrolyl, pyrrolidinyl, imidazolyl, triazolyl, thiazolyl, tetrazolyl, oxazolyl, isoxazolyl, pyrazolyl,

pyridyl, pyrimidinyl, pyrazinyl, pyridazinyl, triazinyl, quinolinyl, iosquinolinyl, quinoxaliny, benzthiazolyl, benzoxazolyl, benzothienyl or benzofuryl.

As used herein, the term "alkyl" refers to straight or branched chain alkyl groups, suitably containing up to 20 and preferably up to 6 carbon atoms, and the term "alkoxy" relates to -O-alkyl groups. The term "alkenyl" and "alkynyl" refer to unsaturated straight or branched chains which include for example from 2-20 carbon atoms, for example from 2 to 6 carbon atoms. In addition, the term "aryl" refers to aromatic groups such as phenyl or naphthyl. The terms "cycloalkyl", "cycloalkenyl" and "cycloalkynyl" refer to such groups which are cyclic and have at least 3 and suitably from 5 to 20 ring atoms. These rings may be fused together to form bicyclic, tricyclic or even larger multiple ring systems.

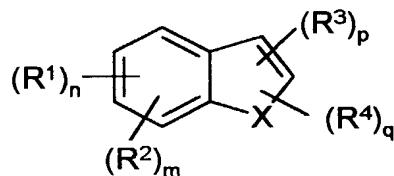
Optionally substituted hydrocarbyl groups will be may be substituted by functional groups, or by other types of hydrocarbyl group. For example, cyclic groups such as aryl, heterocyclic or cycloalkyl, cycloalkenyl or cycloalkynyl may be substituted by hydrocarbyl chains such as alkyl, alkenyl or alkynyl groups as well as functional groups. Where the hydrocarbyl group itself an alkyl, alkenyl or alkynyl group, it may be substituted with cyclic groups such as heterocyclic groups, aryl groups, cycloalkyl, cycloalkenyl or cycloalkynyl groups, as described above, which may themselves be further substituted by hydrocarbyl or functional groups.

The term "functional group" refers to reactive groups such as halo, cyano, nitro, oxo,  $C(O)OR^a$ ,  $C(O)R^a$ ,  $OC(O)R^a$ ,  $OR^a$ ,  $S(O)_tR^a$ ,  $NR^bR^c$ ,  $OC(O)NR^bR^c$ ,  $C(O)NR^bR^c$ ,  $-NR^bC(O)OR^a$ ,  $-NR^bC(O)R^a$ ,  $-NR^aCONR^bR^c$ ,  $=NOR^a$ ,  $-N=CR^bR^c$ ,  $S(O)_tNR^bR^c$  or  $-NR^bS(O)_tR^a$  where  $R^a$ ,  $R^b$  and  $R^c$  are independently selected from hydrogen or optionally substituted hydrocarbyl, or  $R^b$  and  $R^c$  together form an optionally substituted ring which optionally contains further heteroatoms such as sulphur,  $S(O)$ ,  $S(O)_2$ , oxygen and nitrogen,  $t$  is 0 or an integer of from 1-3.

The term "heteroatom" as used herein refers to non-carbon atoms such as oxygen, nitrogen, selenium or sulphur atoms as mentioned above. Where the nitrogen atoms are present, they will generally be present as part of an amino residue so that they will be substituted for example by hydrogen or alkyl.

The term "amide" is generally understood to refer to a group of formula  $C(O)NR^bR^c$  where  $R^b$  and  $R^c$  are hydrogen or an optionally substituted hydrocarbyl group.

In particular, the compounds of the invention are liquid crystal compounds of general formula (I)



(I)

where X is O, S or Se,

- 5 each  $R^1$  and  $R^3$  are independently selected from cyano, halo, optionally substituted hydrocarbyl, optionally substituted alkoxy, optionally substituted heterocyclyl, a group  $R^{13}C(O)O-$  where  $R^{13}$  is optionally substituted hydrocarbyl or carboxy or a hydrocarbyl ester or amide thereof, provided that at least one of group  $R^1$  or  $R^3$  is other than cyano or halo,
- 10 each  $R^2$  and  $R^4$  is independently selected from halo, nitro, lower alkyl optionally substituted by halo, or a group  $R^{14}C(O)O-$  where  $R^{14}$  is optionally substituted hydrocarbyl,
- $n$  is 1 or 2,  $m$  is 0, 1, 2 or 3,  $p$  is 1 or 2 and  $q$  is 0 or 1, provided  $n + m$  does not exceed 4 and  $p + q$  does not exceed 2, and further provided the compounds are other than
- 15 those described in DE1990517 or WO 98/04544.

These compounds have useful liquid crystal properties. In some cases, they have wider nematic phase ranges than the equivalent biphenyl compounds. They have good solubility properties, being soluble in standard host mixtures and exhibit good mixture properties.

- 20 For example, in formula (I), where X is O, S or Se, each  $R^1$  and  $R^3$  are independently selected from cyano, halo, optionally substituted hydrocarbyl, optionally substituted alkoxy, optionally substituted heterocyclyl, or carboxy or a hydrocarbyl ester or amide thereof, provided that at least one of group  $R^1$  or  $R^3$  is other than cyano or halo,
- 25 each  $R^2$  and  $R^4$  is independently selected from halo, nitro, lower alkyl optionally substituted by halo, or a group  $R^{14}C(O)O-$  where  $R^{14}$  is optionally substituted hydrocarbyl,

n is 1 or 2, m is 0, 1, 2 or 3, p is 1 or 2 and q is 0 or 1, provided  $n + m$  does not exceed 4 and  $p + q$  does not exceed 2, and further provided the compounds are other than those described in DE1990517 or WO 98/04544.

Preferably, in the compound of formula (I), n is 1, and m is 0, 1 or 2, and more preferably 0 or 1 and most preferably 0.

Preferably p is 1 and q is 0.

Suitable lower alkyl groups for  $R^2$  and  $R^4$  include methyl, fluoromethyl or trifluoromethyl.

Preferably, any group  $R^2$  or  $R^4$  which are present are halo, especially fluoro.

Suitably no more than two of the groups  $R^1$  and  $R^2$  are fluoro, and preferably no more than one of the groups  $R^1$  and  $R^2$  is fluoro. It has been found that  $\Delta\epsilon$  of the mixtures containing the fluorinated compounds of formula (I) are reduced compared to the mixtures which include non-fluorinated compounds of formula (I). Furthermore, the presence of fluorines at the position  $R^2$  appears to impart more negative behaviour on the mixture.

The applicants have also found that where groups  $(R^2)_m$  is/are fluorine, the compounds may show only nematic phases, and have no smectic phase. mixtures and in all cases are much reduced on the cyano equivalent mixture PBS22.

Where  $R^2$  or  $R^4$  is a group of formula  $R^{14}C(O)O-$ ,  $R^{14}$  is suitably alkyl, cycloalkyl or aryl, preferably alkyl or aryl.

Suitably at least one of  $R^1$  or  $R^3$  is cyano, in particular where low  $\Delta\epsilon$  is required.

In a particularly preferred embodiment, one of  $R^1$  or  $R^3$  is cyano or halo and the other is optionally substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or an ester thereof.

For example, one of  $R^1$  or  $R^3$  is cyano or halo and the other is optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or an ester thereof.

Suitably  $R^1$  and  $R^3$ , when they are other than cyano or halo, are selected from optionally substituted alkyl, optionally substituted alkenyl, optionally substituted

alkynyl, an optionally substituted aryl, optionally substituted cycloalkyl, optionally substituted cycloalkenyl or optionally substituted cycloalkynyl.

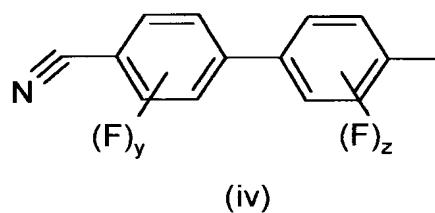
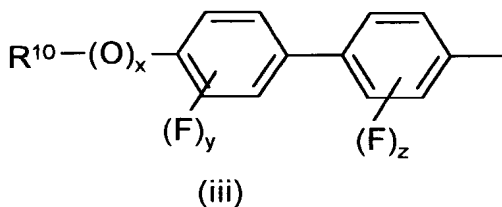
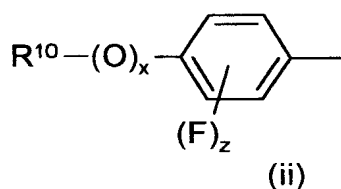
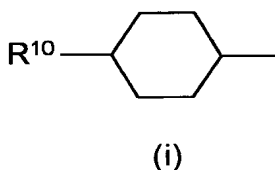
Suitable optional substituents for alkyl, alkenyl, alkynyl, groups  $R^1$  and  $R^3$  include functional groups as defined above, as well as aryl, cycloalkyl, heterocyclyl  
 5 any of which may be substituted by alkyl, alkenyl or alkynyl as well as functional groups as defined above.

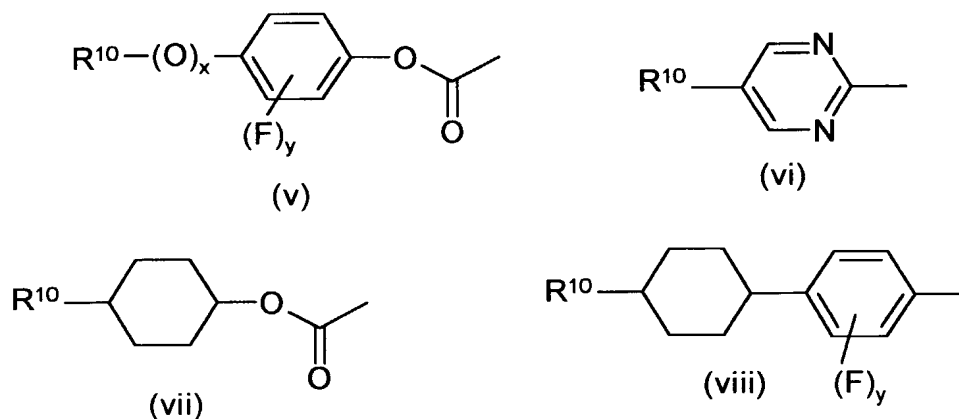
Suitable optional substituents for aryl, heterocyclyl, cycloalkyl, cycloalkenyl or cycloalkynyl groups  $R^1$  and  $R^3$  include those listed above in respect of alkyl, alkyenyl and alkynyl groups, as well as alkyl, alkenyl or alkynyl, any of which may be  
 10 optionally substituted by a functional group, an aryl group, a heterocyclic group or a cycloalkyl, cycloalkenyl or cycloalkynyl group.

Preferably,  $R^1$  and  $R^3$ , where these are other than cyano or halo, are selected from optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or a  
 15 hydrocarbylester thereof.

Where these are carboxy ester groups, they are preferably alkyl esters or aryl esters such as phenyl esters where the phenyl group may be optionally substituted for example with alkyl, alkoxy or cyano groups.

Suitable groups  $R^1$  or  $R^3$  where these are other than cyano or halo are groups of  
 20 formula (i), (ii), (iii), (iv), (v), (vi), (vii) or (viii)





where  $x$  is 0 or 1,  $R^{10}$  is an  $C_{1-20}$ alkyl group, and  $y$  and  $z$  are independently  
 5 selected from 0, 1 or 2.

Preferably at least one  $R^1$  or  $R^3$  group is a group of sub-formula (i) – (viii) as set out above.

A particularly preferred group for  $R^1$  or  $R^3$  where these are other than cyano or halo are optionally substituted cycloalkyl or optionally substituted phenyl, and  
 10 particularly optionally substituted phenyl.

Suitable substituents for the cycloalkyl or phenyl groups  $R^1$  and  $R^3$  include halo, alkyl especially  $C_{3-9}$ alkyl, alkoxy such as  $C_{3-9}$ alkoxy, cyano or phenyl which may itself be substituted by alkyl or cyano. Particularly suitable substituents include alkyl especially  $C_{3-9}$ alkyl, alkoxy such as  $C_{3-9}$ alkoxy, cyano or phenyl which may itself be  
 15 substituted by alkyl or cyano.

When  $R^1$  or  $R^3$  is a group is a group of formula  $R^{13}C(O)O-$ ,  $R^{13}$  is suitably alkyl, cycloalkyl or aryl, preferably cycloalkyl.

The selection of either  $R^1$  or  $R^3$  as cyano can have significant effects on the properties of the compounds. For example, compounds where  $R^1$  is cyano may have a  
 20 significantly different dielectric anisotropy as compared to compounds where  $R^3$  is cyano. It has been found also that the birefringence of mixtures containing the compounds of the invention are lower when  $R^3$  is cyano in preference to  $R^1$ .

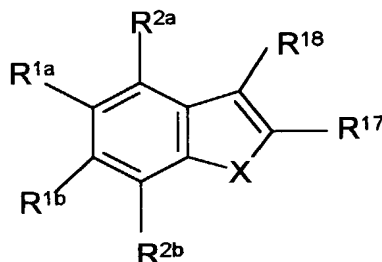
Preferably  $X$  is oxygen or sulphur and most preferably oxygen.

Suitably substituents are arranged on the ring so as to confer an advantageous  
 25 dipole on the compound. For this purpose, the substituents are suitably arranged such that the overall shape of the molecule is either bent or wedge shaped. Thus



substituents are suitably positioned at the 2 and 6 positions of the bicyclic ring where the group X is at position 1.

In particular, the invention provides a compound of general formula (IA)



(IA)

where X is oxygen, sulphur or selenium, R<sup>1a</sup> and R<sup>1b</sup> are independently selected from hydrogen, cyano, halo, optionally substituted hydrocarbyl, optionally substituted heterocyclyl or carboxy or a hydrocarbyl ester or amide thereof, provided that at least one group R<sup>1a</sup> or R<sup>1b</sup> is other than hydrogen;

- one of R<sup>17</sup> or R<sup>18</sup> is cyano, halo, optionally substituted hydrocarbyl, optionally substituted heterocyclyl or carboxy or a hydrocarbyl ester or amide thereof, and the other is hydrogen, halo, nitro, lower alkyl optionally substituted by halo, or a group R<sup>15</sup>C(O)O- where R<sup>15</sup> is an optionally substituted hydrocarbyl group; R<sup>2a</sup> and R<sup>2b</sup> are independently selected from hydrogen, halo, nitro, lower alkyl optionally substituted by halo, or a group R<sup>14</sup>C(O)O- where R<sup>14</sup> is as defined above; subject to the provisos that:

- (i) at least one group R<sup>1a</sup> or R<sup>1b</sup> or R<sup>17</sup> or R<sup>18</sup> is other than cyano or halo;
- (ii) where X is S, R<sup>17</sup> is carboxy or a hydrocarbyl ester or amide thereof, R<sup>18</sup> is hydrogen, R<sup>2a</sup> and R<sup>2b</sup> are not both fluoro;
- (iii) where X is O, R<sup>1</sup> is an optionally substituted hydrocarbyl or carboxy or a hydrocarbyl ester or amide thereof, R<sup>2a</sup> is hydrogen, and R<sup>1b</sup> and R<sup>2b</sup> are both fluorine, then R<sup>17</sup> is other than C<sub>1-8</sub> alkyl.

Where R<sup>17</sup> is a group R<sup>15</sup>C(O)O-, R<sup>15</sup> is suitably a group of formula R<sup>13</sup> as defined above. Alternatively where R<sup>18</sup> is a group of formula R<sup>15</sup>C(O)O-, R<sup>15</sup> is suitably a group R<sup>14</sup> as defined above.

Preferably in the compound of formula (IA) R<sup>2a</sup> is hydrogen.

Suitably at least one of  $R^{1b}$ ,  $R^{2b}$  or  $R^{18}$  in formula (IA) is fluoro. However, suitably no more than two of  $R^{1a}$ ,  $R^{2a}$ ,  $R^{2b}$  or  $R^{1b}$  are fluoro, and preferably no more than one of these groups is fluoro.

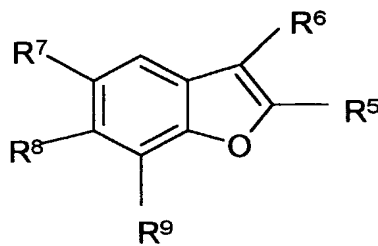
5 Preferably one of  $R^{1b}$  or  $R^{1a}$  or  $R^{17}$  or  $R^{18}$  in formula (IA) is cyano or halo and at least one of the said groups on the other ring of the bicyclic ring of formula (IA) is optionally substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or a hydrocarbyl ester thereof.

Thus for example, where  $R^{1b}$  or  $R^{1a}$  is halo or cyano, at least one of  $R^{17}$  or  $R^{18}$  is  
 10 optionally substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or a hydrocarbyl ester thereof. Conversely, where where  $R^{17}$  or  $R^{18}$  is halo or cyano, at least one of  $R^{1a}$  or  $R^{1b}$  is optionally substituted  
 15 substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or a hydrocarbyl ester thereof

For instance, one of  $R^{1b}$  or  $R^{1a}$  or  $R^{17}$  or  $R^{18}$  in formula (IA) is cyano or halo and at least one of the said groups on the other ring of the bicyclic ring of formula (IA) is optionally substituted alkyl, optionally substituted alkenyl, optionally substituted  
 20 alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or a hydrocarbyl ester thereof.

Particular examples of said optionally substituted cycloalkyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or a hydrocarbyl ester thereof are groups of formula (i)-(viii) as set out above.

25 A particularly preferred group of compounds of the invention are of formula (II)



(II)

wherein  $R^5$  is a group  $R^3$  as defined above in relation to formula (I),  
one of  $R^7$  and  $R^8$  is a group  $R^1$  as defined in relation to formula (I) and the other is  
hydrogen or a group  $R^1$  as defined in relation to formula (I);

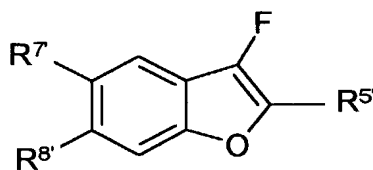
$R^6$  is hydrogen, cyano or fluoro, preferably hydrogen or fluoro, and

5  $R^9$  is hydrogen, cyano or fluoro,

provided that where  $R^5$  is cyano or fluoro, at least one of  $R^7$  or  $R^8$  is optionally  
substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl,  
optionally substituted alkynyl, optionally substituted alkoxy, optionally substituted aryl,  
optionally substituted heterocyclyl, carboxy or an ester thereof; and where one of  $R^7$  or  
10  $R^8$  is cyano or fluoro and the other is hydrogen,  $R^5$  is optionally substituted alkyl,  
optionally substituted alkenyl, optionally substituted alkynyl, optionally substituted  
alkoxy, optionally substituted aryl, optionally substituted heterocyclyl, carboxy or an  
ester thereof.

Preferred groups  $R^5$  and  $R^7$  and/or  $R^8$  include cyano; fluoro; alkoxy; alkenyl;  
15 alkyl, aryl or alkylaryl esters of carboxy; arylalkyl, alkenylaryl wherein the aryl ring is  
optionally substituted with an alkyl group, a functional group such as fluoro or alkoxy,  
or further aryl groups which are themselves optionally substituted with alkyl;  
optionally substituted pyrimidinyl wherein the optional substituents are in particular  
alkyl or optionally substituted cycloalkyl where the cycloalkyl ring is optionally  
20 substituted with an alkyl group.

Specific examples of compounds of formula (II) are compounds of  
formula (IIA)



(IIA)

25

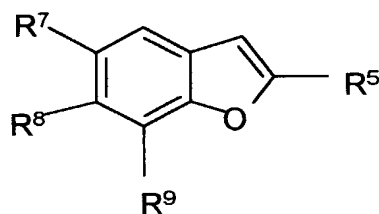
where  $R^{5'}$  is cyano or fluoro, preferably fluoro, one of  $R^{7'}$  and  
 $R^{8'}$  is hydrogen and the other is an optionally substituted  
hydrocarbyl group or a heterocyclic group as described above. Particular examples of  
substituted hydrocarbyl groups for  $R^{7'}$  or  $R^{8'}$  are groups of sub-formula (i), (ii), (iii),  
30 (vi) or (viii) as defined above.

Compounds of formula (IIA) may show advantageous properties in terms of their u.v. stability and a low susceptibility to ion contamination, making them particularly suitable for use in thin film transmittor (TFT) devices.

Particular examples of the compounds of formula (II) are listed in Table 1.


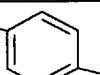

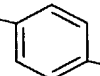

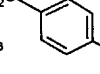

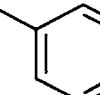
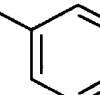
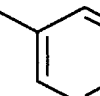

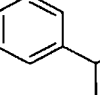


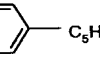

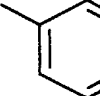
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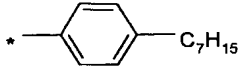
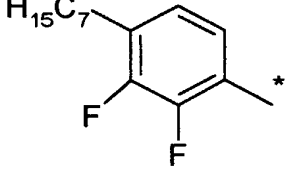
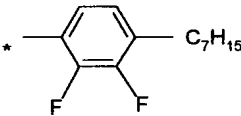
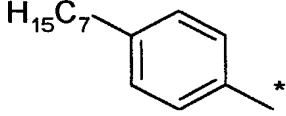
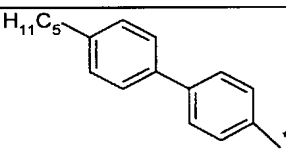
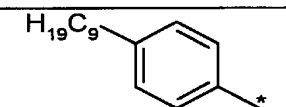
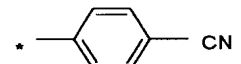
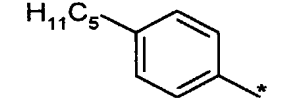
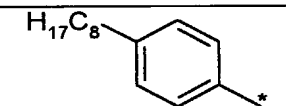
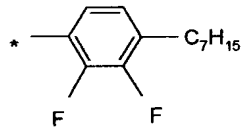
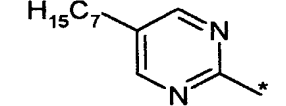
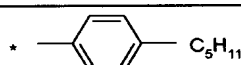
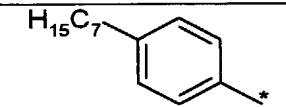
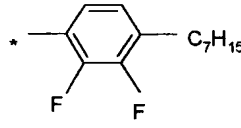
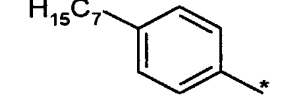
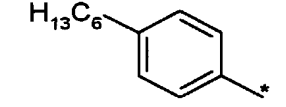
Table 1

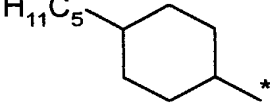
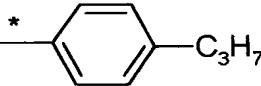
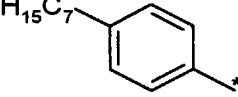
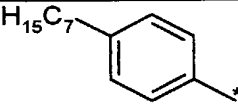
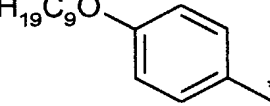
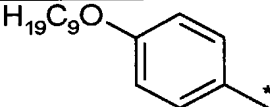
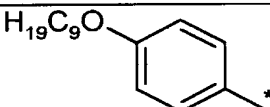
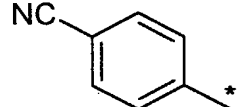
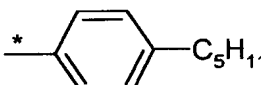
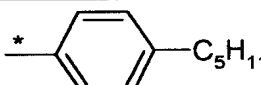
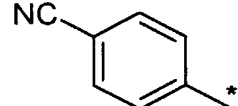
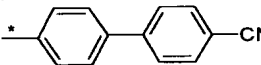


No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
1	-OC <sub>8</sub> H <sub>17</sub>			H
2	-CO <sub>2</sub> C <sub>2</sub> H <sub>5</sub>		H	H
3	CN		H	H
4			H	H
5			H	H
6			H	H
7			H	H

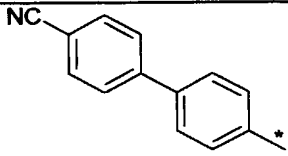
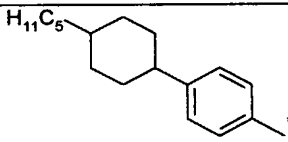
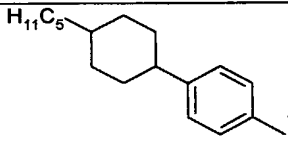
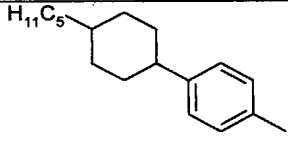
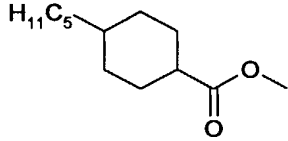
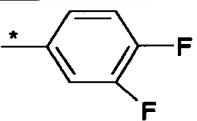
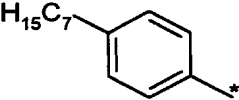
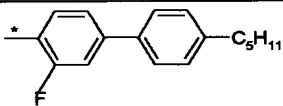
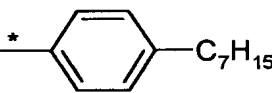
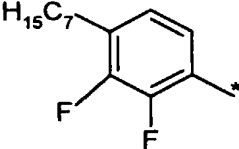
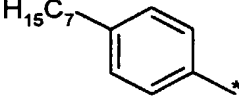
No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
8			H	H
9			H	H
10		CO <sub>2</sub> CH <sub>3</sub>	H	H
11			H	H
12		CN	H	H
13			H	H
14		CN	H	H
15			H	H
16	CN		H	H
17			H	H
18			H	H
19			H	H

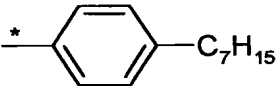
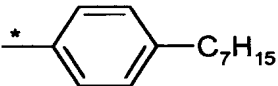
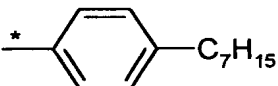
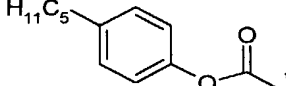
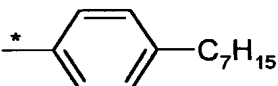
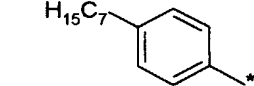
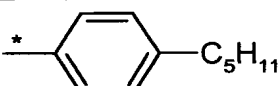
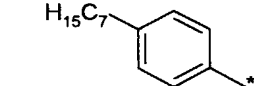
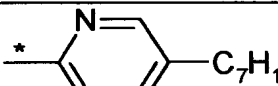
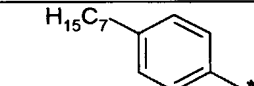

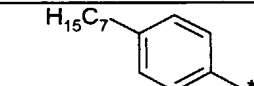
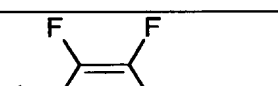
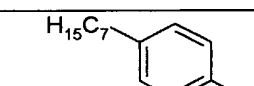
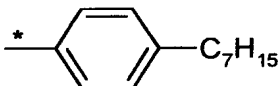
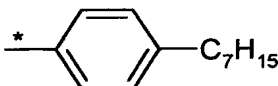
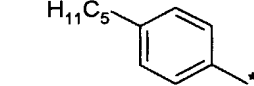
No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
20	*-  -C <sub>7</sub> H <sub>15</sub>	H <sub>9</sub> C <sub>4</sub> O-  -O-C(=O)-CH <sub>3</sub> *	H	H
21	*-  -C <sub>7</sub> H <sub>15</sub>	H <sub>13</sub> C <sub>6</sub> O-  -O-C(=O)-CH <sub>3</sub> *	H	H
22	*-  -C <sub>7</sub> H <sub>15</sub>	H <sub>6</sub> C <sub>2</sub> HCH <sub>2</sub> C(CH <sub>3</sub> )-  -O-C(=O)-CH <sub>3</sub> *	H	H
23	*-  -C <sub>7</sub> H <sub>15</sub>	H <sub>13</sub> C <sub>6</sub> HC(CH <sub>3</sub> )-O-C(=O)-CH <sub>3</sub> *	H	H
24	*-C(=O)-O-CH <sub>3</sub>	H <sub>15</sub> C <sub>7</sub> -  *	H	H
25	CN	H <sub>7</sub> C <sub>3</sub> -  *	H	H
26	CN	H <sub>11</sub> C <sub>5</sub> -  *	H	H
27	*-  -C <sub>5</sub> H <sub>11</sub>	CN	H	H
28	CN	H <sub>11</sub> C <sub>5</sub> -  -  *	H	H
29	*-  -  -C <sub>9</sub> H <sub>11</sub>	CN	H	H
30	*-  -C <sub>7</sub> H <sub>15</sub>	H <sub>11</sub> C <sub>5</sub> -  *	H	H

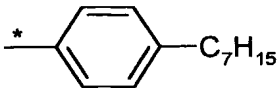
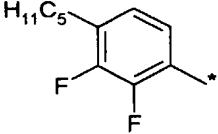
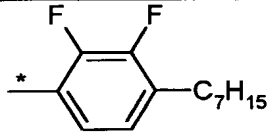
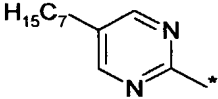
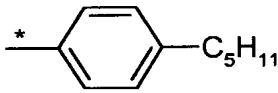
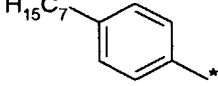
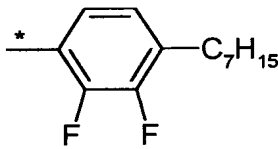
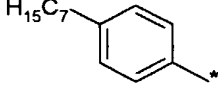
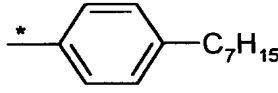
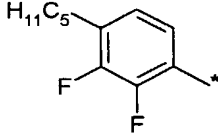
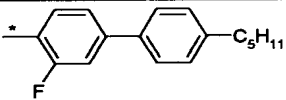
No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
31			H	H
32			H	H
33	C <sub>7</sub> H <sub>15</sub>		H	H
34	CN		H	H
35			H	H
36	CN		H	H
37			H	H
38			F	F
39			F	F
40	CN		H	H

No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
41	CN		H	H
42		CN	H	H
43	CO <sub>2</sub> H		H	H
44	CONH <sub>2</sub>		H	H
45	CO <sub>2</sub> CH <sub>3</sub>		H	H
46	CO <sub>2</sub> H		H	H
47	CONH <sub>2</sub>		H	H
48	C <sub>7</sub> H <sub>15</sub>		H	H
49		Br	H	H
50			H	H
51		C <sub>5</sub> H <sub>11</sub>	H	H



No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
52	C <sub>5</sub> H <sub>11</sub>		H	H
53	CO <sub>2</sub> H		H	H
54	CONH <sub>2</sub>		H	H
55	CN		H	H
56	CN		H	H
57			H	H
58		C <sub>7</sub> H <sub>15</sub>	F	F
59			F	F
60	C <sub>7</sub> H <sub>15</sub>	C <sub>2</sub> H <sub>5</sub> OC(O)-	H	H
61	C <sub>7</sub> H <sub>15</sub>	H <sub>11</sub> C <sub>5</sub> C≡C-	H	H
62	- C(O)OCH(CH <sub>3</sub> )C <sub>6</sub> H <sub>11</sub> 3		H	H

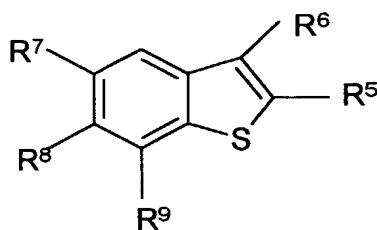
No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
63		CO <sub>2</sub> H	H	H
64		CO <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub>	H	H
65			H	H
66			H	H
67			H	H
68			H	H
69			H	H
70			H	H
71		-C≡C-C <sub>5</sub> H <sub>11</sub>	H	H
72			H	H

No.	R <sup>5</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
73			H	H
74			H	H
75			H	H
76			H	H
77			F	F
78		C <sub>7</sub> H <sub>15</sub>	F	F

In the above Table, \* indicates the point of attachment to the ring structure.

Particular examples of compounds of formula (I) where X is sulphur are listed in Table 2.

Table 2

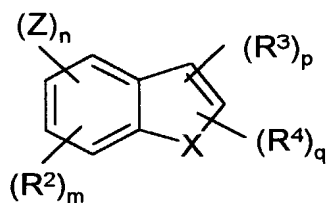


No.	R <sup>5</sup>	R <sup>6</sup>	R <sup>7</sup>	R <sup>8</sup>	R <sup>9</sup>
100	-CO <sub>2</sub> H	H		H	H
101	-CONH <sub>2</sub>	H		H	H
102	CN	H		H	H

The compounds of the invention may be prepared by conventional methods  
 5 which would be apparent to a skilled chemist.

In particular, compounds may be prepared by adding substituents to a bicyclic  
 ring.

Thus, for example, a compound of formula (I) can be prepared by reacting a  
 compound of formula (III)



(III)

where R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, X, n, m, p and q are as defined in relation to formula (I), and  
 Z is either a leaving group or a group B(OH)<sub>2</sub>, with a compound of formula (IV)



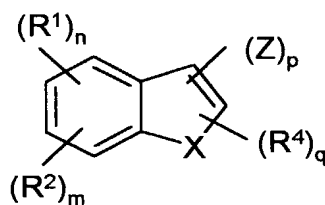
(IV)

where R<sup>1</sup> is as defined in relation to formula (I) and Z' is a group B(OH)<sub>2</sub>  
 where Z is a leaving group, or a leaving group where Z is a group B(OH)<sub>2</sub>;

and thereafter if desired or necessary, converting a group  $R^2$ ,  $R^3$  or  $R^4$  to a different such group.

Suitable leaving groups for Z or Z' include halo such as bromo or iodo, mesylate, tosylate and triflate. The reaction is suitably effected in an inert organic solvent, such as 1,2-dimethoxyethane in the presence of a base such as sodium or potassium carbonate. The reaction is suitably effected in the presence of an inert atmosphere such as a nitrogen atmosphere. Optionally a catalyst such as a palladium catalyst for example tetrakis (triphenylphosphine) palladium is present. The reaction is suitably effected at elevated temperatures, for instance at the reflux temperature of the solvent.

Of course, other substituents may be introduced in an analogous way and the order in which this is done will depend to a large extent on the nature of the substituents and where they are positioned on the ring. In an alternative route, for example, compounds of formula (I), are prepared by reacting a compound of formula (V)



(V)

where  $R^1$ ,  $R^2$ ,  $R^4$ , X, n, m, p and q are as defined in relation to formula (I), and Z is as defined in relation to formula (III), with a compound of formula (VI)



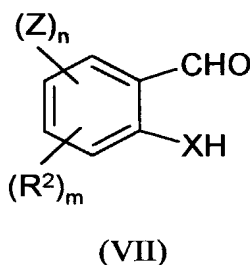
(VI)

where  $R^3$  is as defined in relation to formula (I) and Z' is as defined in relation to formula (IV), and thereafter, if necessary, changing any groups  $R^1$ ,  $R^2$  and  $R^4$  to different such groups.

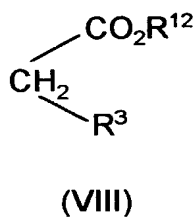
Suitable leaving groups Z or Z' and reaction conditions will be similar to those described above in relation to the reaction between compounds of formula (III) and (IV).

The conversion of groups  $R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  to different such groups could be carried out by conventional methods as would be apparent to a skilled chemist. A particularly useful reaction in this context is the conversion of a carboxylic ester group such as an alkyl ester, in particular an ethyl ester, to a cyano group. This reaction may be achieved by hydrolysis of the carboxylic ester group, followed by conversion of the resultant carboxylic acid to the corresponding acid chloride and thereafter to the amide. Dehydration of the amide gives the cyano compound. Each of the steps can be carried out using conventional chemistry and these are illustrated in the Examples given hereinafter.

Compounds of formula (III) and (V) are suitably prepared by a cyclisation reaction as would be understood in the art. For example, a compound of formula (III) might be prepared by reacting a compound of formula (VII)



where X, n and m are as defined in relation to formula (I), and Z is as defined in relation to formula (III), with a compound of formula (VIII)



where  $R^3$  is as defined above in relation to formula (I) and  $R^{12}$  is an alkyl group such as ethyl. Thereafter, groups  $R^3$  can be changed to different such groups on the compound of formula (III) in a similar manner to that outlined above.

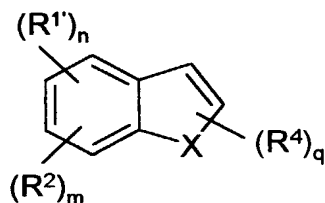
A particular preferred compound of formula (VIII) is a compound where  $R^3$  is a carboxylic ester group such as an alkyl ester group as this gives rise to the possibility of subsequent modification as outlined above. Thus a suitable compound of formula (VIII) is diethyl bromomalonate.

The reaction is suitably effected in an organic solvent such as butanone in the presence of a base such as potassium carbonate.

Compounds of formulae (IV) and (VI) are either known compounds or they can be prepared by conventional methods. For example where Z or Z' are B(OH)<sub>2</sub> groups, these may be prepared by reacting the corresponding halo substituted compounds with magnesium in an organic solvent such as tetrahydrofuran, then with trimethyl borate, and finally acidifying the product using a mineral acid such as hydrochloric acid. Examples of such preparations are illustrated hereinafter.

Compounds of formula (XI) and (XII) are either known compounds or they can be prepared from known compounds by conventional methods.

In an alternative approach, compounds of formula (I) where q is 0 and p is 1 and R<sup>3</sup> is a carboxy group may be prepared by introduction of a substituent R<sup>3</sup> group to a compound of formula (IX)



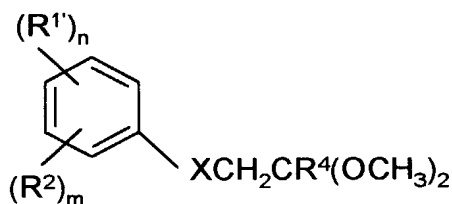
(IX)

were R<sup>2</sup>, R<sup>4</sup>, X, m, n and q are as defined in relation to formula (I), and R<sup>1'</sup> is a group R<sup>1</sup> as defined in relation to formula (I) or a precursor thereof, with a carboxylating agent such as Cardice in the presence of a base such as n-butyllithium and an organic solvent such as tetrahydrofuran, and thereafter acidifying the product with an acid such as glacial acetic acid. The carboxy group can subsequently be converted into different R<sup>3</sup> groups as required.

Suitable precursor groups R<sup>1'</sup> include groups which can be converted to the desired R<sup>1</sup> groups by conventional chemistry. Thus an example of such a group would be a group Z or Z' as defined above.

Compounds of formula (IX) where R<sup>1'</sup> is a group R<sup>1</sup> (hereinafter referred to as compounds of formula (IXA)) may have liquid crystal properties in their own right and therefore these form a further aspect of the invention.

Compounds of formula (IX) where q is 0 may be prepared by cyclisation of an acetal compound of formula (X)



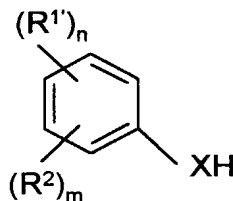
(X)

5

where  $R^2$ ,  $R^4$ ,  $X$ ,  $n$  and  $m$  are as defined in relation to formula (I), and  $R^{1'}$  is as defined in relation to formula (IX); in the presence of polyphosphoric acid. The reaction is suitably effected in an organic solvent such as chlorobenzene at elevated temperature, for example at the reflux temperature of the solvent.

10

Compounds of formula (X) are suitably prepared by reacting a compound of formula (XI)



(XI)

15

where  $R^{1'}$ ,  $R^2$ ,  $X$ ,  $m$  and  $n$  are as defined above, with a compound of formula (XII)



(XII)

20

where  $R^4$  is as defined in relation to formula (I) and  $Z''$  is a leaving group. Suitable leaving groups  $Z''$  are defined above in relation to the group  $Z$ . The reaction is suitably effected in the presence of a base such as potassium carbonate in an organic solvent such as butanone.

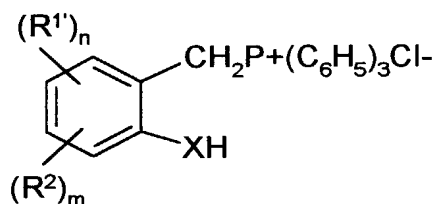
25

Compounds of formula (IX) may be converted to compounds of formula (V) where  $Z$  is a  $B(OH)_2$  group by reaction with trimethyl borate in the presence of a base



such as n-butyl lithium. Subsequent acidification with an acid such as hydrochloric acid will yield the desired product. The reaction is suitably effected in an organic solvent such as tetrahydrofuran and reactions of this type are exemplified hereinafter.

An alternative cyclisation route which can lead directly to compounds of formula (I) where q is 0 involves reaction of a compound of formula (XIII)



(XIII)

where  $R^{1'}$ ,  $R^2$ , X, n and m are as defined above, with a compound of formula (XIV)

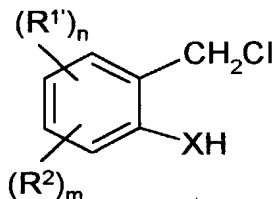


(XIV)

where  $R^{3'}$  is a group  $R^3$  as defined in relation to formula (I) or a precursor thereof. The reaction is suitably effected in an organic solvent such as dichloromethane in the presence of a base such as N,N'-dicyclocarbodiimide (DCC) and 4-N,N'-dimethylaminopyridine (DMAP). The reaction is suitably carried out under an inert atmosphere for example of nitrogen.

Precursor groups  $R^{3'}$  may be similar to those defined above in relation to  $R^{1'}$ .

Compounds of formula (XIII) may be derived from compounds of formula (XIV)



(XIV)

where  $R^{1'}$ ,  $R^2$ , X, n and m are as defined above with triphenylphosphine under conditions such as those illustrated hereinafter.

Variations and modifications to these routes would be apparent to the skilled person and these are all encompassed by the invention.

5           The compounds of the invention can be selected such that their liquid crystal properties, in particular the nematic/smectic properties, suit the desired application. This may be achieved by varying the substituent groups on the central ring structure as outlined above, or it may be effected by mixing the compounds with other compounds of the invention or other different liquid crystal compounds. Mixtures are suitably  
10           eutectic mixtures. The compounds of the present invention may be mixed with each other to form useful liquid crystal mixtures, they may also be used with liquid crystal polymers or other low molar mass non-polymer liquid crystal materials.

          As would be appreciated, the compounds of the invention can be used in a wide variety of devices, depending upon their particular properties. For applications where  
15           nematic compounds are required, compounds with low melting points, high transition temperatures ( $TN-I(^{\circ}C)$ ), low viscosity and high dipole moments giving for example high values of ( $\Delta\epsilon$ ) are required. Compounds of the invention include those which have such properties and other properties such as flexoelectric properties. Where the melting point is not sufficiently low, this may be reduced by mixing the compound of  
20           the invention with other liquid crystal compounds, in particular a different compound of the invention, so as to form a mixture, preferably a eutectic mixture.

          Transition temperatures may be increased by using or including in the mixture compounds of the invention which comprise at least three carbocyclic, heterocyclic or aryl ring systems, for example, compounds of formula (I) where both  $R^1$  and  $R^3$   
25           comprise a carbocyclic, heterocyclic or aryl group.

          For trifluoroterphenyl (TFT) devices, compounds of the invention with TN twisted nematic values of the order of  $90^{\circ}$  are suitably selected. This is indicative of the degree of twist present in the alignment of the molecules. The viscosity of such compounds ( $\Delta n$ ) is suitably low and for this reason, compounds with saturated  
30           substituent groups may be preferred. The compounds should have a positive  $\Delta\epsilon$ , which is a result of a longitudinal dipole moment. The value of the elastic constants ratio,  $K_{11}/K_{33}$ , is preferably high, whilst the conductivity is preferably low. In order to

achieve these latter requirements, halo substituents such as fluoro may be preferred to cyano substituents.

Compounds of the invention may have the properties of the so called "super-twist nematics" where the TN values are of the order of 240-270°. Such compounds generally have a high  $\Delta n$  value, and so may contain aromatic rings. They will have a positive  $\Delta\epsilon$  and the value of  $K_{11}/K_{33}$  is high to provide a sharp threshold.

Liquid crystal devices comprising compounds of the invention or mixtures form a further aspect of the invention. Examples of such devices include optical and electro-optical devices, magneto-optical devices and devices providing responses to stimuli such as temperature changes and total or partial pressure changes. The compounds described above may also be included in a mixture, where the mixture comprises at least two compounds. Typical mixtures include mixtures consisting of compounds of the above-described compounds and also mixtures comprising at least one compound as described and at least one different liquid crystal compound.

When a smectic A phase compound of the invention is composed of chiral molecules, it may exhibit an electroclinic effect, i.e. a direct coupling of molecular tilt to applied field. The origin of the electroclinic effect in a smectic A phase composed of chiral polar molecules has been described by Garoff and Meyer as follows. The application of an electric field parallel to the smectic layers of such a smectic A phase biases the free rotation of the transverse molecular dipoles and therefore produces a non-zero average of the transverse component of the molecular polarisation. When such a dipole moment is present and coupled to the molecular chirality, a tilt of the long molecular axis (the director) is induced in a plane perpendicular to the dipole moment.

In thin samples, for example 1-3  $\mu\text{m}$ , and with the smectic layers tilted or perpendicular with respect to the glass plates the electroclinic effect is detectable at low applied fields.

In an aligned smectic A sample a tilt of the director is directly related to a tilt of the optic axis. The electroclinic effect results in a linear electro-optic response. The electro-optic effect can manifest itself as a modulation of the effective birefringence of the device.

Electroclinic (EC) devices are useful, for example, in spatial light modulators having an output that varies linearly with applied voltage. A further advantage of EC devices is that they have high speed response times, much faster than twisted nematic

type devices. One known type of ferroelectric device is bistable, in contrast the EC device is not bistable and has an output that varies linearly with applied voltage.

The electroclinic effect is sometimes referred to as the soft-mode effect see G Andersson et al in Appl. Phys. Lett., 51, 9, (1987).

5 In general terms, regarding the electroclinic effect, it is advantageous if on applying a small voltage there results a large induced tilt. An increase in induced tilt may result in an increase in contrast ratio. It is also advantageous if a large induced tilt can be obtained at as low a voltage as possible.

10 It is also advantageous if the relationship between molecular induced tilt and applied voltage is temperature independent. When an increase in applied voltage results in little or no change in induced tilt then the material being tested is generally referred to as exhibiting a saturation voltage effect.

$$15 \quad d = \frac{(2m+1)\lambda}{4(\Delta n)}$$

There are a variety of electroclinic devices in which the compounds of the present invention may be incorporated. For example, in a liquid crystal cell active black plane driving may be utilised. One of the walls forming the cell may be formed from a silicon substrate e.g. a wafer which possesses circuitry for driving pixels.

For many of these devices there exists an optimum thickness for the cell which is related to the birefringence ( $\Delta n$ ) given by: wherein

$\lambda$  = wavelength of operation

$\Delta n$  = birefringence of liquid crystalline material

25  $m$  = integer.

Some suitable methods for driving electroclinic devices described by the present invention may be found in UK patent application GB-2 247 972 A.

The mode of operation of these devices includes either amplitude modulation or phase modulation. Similarly devices may be used in reflectance or transmissive mode.

30 By  $S_A^*$  is meant a  $S_A$  phase which contains some proportion of chiral molecules, and therefore it is preferable that the compounds of the invention used in this way are chiral.

Cholesteric or chiral nematic liquid crystals possess a twisted helical structure which is capable of responding to a temperature change through a change in the helical pitch length. Therefore as the temperature is changed, then the wavelength of the light reflected from the planar cholesteric structure will change and if the reflected light covers the visible range then distinct changes in colour occur as the temperature varies. This means that there are many possible applications including the areas of thermography and thermooptics.

The cholesteric mesophase differs from the nematic phase in that in the cholesteric phase the director is not constant in space but undergoes a helical distortion. The pitch length for the helix is a measure of the distance for the director to turn through 360°.

By definition, a cholesteric material is chiral material. Chiral compounds of the invention may exhibit a helical mesophase and so may be used in thermographic or thermooptic applications. Chiral compounds of the invention may also be used in electro-optical displays as dopants, for example in twisted nematic displays where they may be used to remove reverse twist defects. They may also be used in cholesteric to nematic dyed phase change displays where they may be used to enhance contrast by preventing wave-guiding.

Thermochromic applications of cholesteric liquid crystal materials usually use thin film preparations of the materials which are then viewed against a black background. These temperature sensing devices may be placed into a number of applications involving thermometry, medical thermography, non-destructive testing, radiation sensing and for decorative purposes. Examples of these may be found in D G McDonnell in Thermotropic Liquid Crystals, Critical Reports on Applied Chemistry, Vol. 22, edited by G W Gray, 1987 pp 120-44; this reference also contains a general description of thermochromic cholesteric liquid crystals.

Generally, commercial thermochromic applications require the formulation of mixtures which possess low melting points, short pitch lengths and smectic transitions just below the required temperature-sensing region. Preferably the mixture or material should retain a low melting point and high smectic - cholesteric transition temperatures.

In general, thermochromic liquid crystal devices have a thin film of cholesterogen sandwiched between a transparent supporting substrate and a black absorbing layer. One of the fabrication methods involves producing an 'ink' with the

liquid crystal by encapsulating it in a polymer and using printing technologies to apply it to the supporting substrate. Methods of manufacturing the inks include gelatin microencapsulation, US patent 3,585,318 and polymer dispersion, US patents 1,161,039 and 3,872,050. One of the ways for preparing well-aligned thin film structures of  
5 cholesteric liquid crystals involves laminating the liquid crystal between two embossed plastic sheets. This technique is described in UK patent 2,143,323.

Other compounds of the present invention or mixtures of these may be used in ferroelectric mixtures and devices. In particular compounds of the invention may be used in many of the known forms of liquid crystal display devices, for example chiral  
10 smectic electro-optic devices. Such a device may comprise a layer of liquid crystal material contained between two spaced cell walls bearing electrode structures and surface treated to align liquid crystal material molecules.

Ferroelectric smectic liquid crystal materials, which can be produced by mixing an achiral host and a chiral dopant, use the ferroelectric properties of the tilted chiral  
15 smectic C, F, G, H, I, J and K phases. The chiral smectic C phase is denoted  $S_C^*$  with the asterisk denoting chirality. The  $S_C$  phase is generally considered to be the most useful as it is the least viscous. Ferroelectric smectic liquid crystal materials should ideally possess the following characteristics: low viscosity, controllable spontaneous polarisation ( $P_s$ ) and an  $S_C$  phase that persists over a broad temperature range which  
20 should include ambient temperature and exhibits chemical and photochemical stability. Materials which possess these characteristics offer the prospect of very fast switching liquid crystal containing devices. Some applications of ferroelectric liquid crystals are described by J S Patel and J W Goodby in Opt. Eng., 1987, 26, 273.

In ferroelectric liquid crystal devices the molecules switch between different  
25 alignment directions depending on the polarity of an applied electric field. These devices can be arranged to exhibit bistability where the molecules tend to remain in one of two states until switched to the other switched state. Such devices are termed surface stabilised ferroelectric devices, e.g. as described in US 5061047 and US 4367924 and US 4563059. This bistability allows the multiplex addressing of quite large and  
30 complex devices.

One common multiplex display has display elements, i.e. pixels, arranged in an X, Y matrix format for the display of for example alpha numeric characters. The matrix format is provided by forming the electrodes on one side as a series of column

electrodes, and the electrodes on the other slide as a series of row electrodes. The intersections between each column and row form addressable elements or pixels. Other matrix layouts are known, e.g. seven bar numeric displays.

There are many different multiplex addressing schemes. A common feature  
5 involves the application of a voltage, called a strobe voltage to each row or line in sequence. Coincidentally with the strobe applied at each row, appropriate voltages, called data voltages, are applied to all column electrodes. The differences between the different schemes lies in the shape of the strobe and data voltage waveforms.

Other addressing schemes are described in GB-2,146, 473-A; GB-2,173,336-A;  
10 GB-2,173, 337-A; GB-2, 173629-A; WO 89/05025; Harada et al 1985 S.I.D. Paper 8.4 pp 131-134; Lagerwall et al 1985 I.D.R.C. pp 213-221 and P Maltese et al in Proc 1988 I.D.R.C. pp 90-101 Fast Addressing for Ferroelectric LC Display Panels.

The material may be switched between its two states by two strobe pulses of opposite sign, in conjunction with a data waveform. Alternatively, a blanking pulse may  
15 be used to switch the material into one of its states. Periodically the sign of the blanking and the strobe pulses may be alternated to maintain a net d.c. value.

These blanking pulses are normally greater in amplitude and length of application than the strobe pulses so that the material switches irrespective of which of the two data waveforms is applied to any one intersection. Blanking pulses may be  
20 applied on a line by line basis ahead of the strobe, or the whole display may be blanked at one time, or a group of lines may be simultaneously blanked.

It is well known in the field of ferroelectric liquid crystal device technology that in order to achieve the highest performance from devices, it is important to use mixtures of compounds which give materials possessing the most suitable ferroelectric smectic  
25 characteristics for particular types of devices.

Devices can be assessed for speed by consideration of the response time vs pulse voltage curve. This relationship may show a minimum in the switching time ( $t_{\min}$ ) at a particular applied voltage ( $V_{\min}$ ). At voltages higher or lower than  $V_{\min}$  the switching time is longer than  $t_{\min}$ . It is well understood that devices having such a minimum in  
30 their response time vs voltage curve can be multiplex driven at high duty ratio with higher contrast than other ferroelectric liquid crystal devices. It is preferred that the said minimum in the response time vs voltage curve should occur at low applied voltage and

at short pulse length respectively to allow the device to be driven using a low voltage source and fast frame address refresh rate.

Typical known materials (where materials are a mixture of compounds having suitable liquid crystal characteristics) which do not allow such a minimum when  
5 included in a ferroelectric device include the commercially available materials known as SCE13 and ZLI-3654 (both supplied by Merck UK Ltd, Poole, Dorset). A device which does show such a minimum may be constructed according to PCT GB 88/01004 and utilising materials such as e.g. commercially available SCE8 (Merck UK Ltd). Other examples of prior art materials are exemplified by PCT/GB 86/00040, PCT GB  
10 87/00441 and UK 2232416B.

Certain compounds of the invention may be useful in laser addressed applications in which laser beams are used to scan across the surface of the material or leave a written impression thereon. For various reasons many of these materials have consisted of organic materials which are at least partially transparent in the visible  
15 region. The technique relies upon localised absorption of laser energy which causes localised heating and in turn alters the optical properties of the otherwise transparent material in the region of contact with the laser beam. Thus as the beam traverses the material, a written impression of its path is left behind. One of the most important of these applications is in laser addressed optical storage devices, and in laser addressed  
20 projection displays in which light is directed through a cell containing the material and is projected onto a screen. Such devices have been described by Khan Appl. Phys. Lett. vol. 22, p111, 1973; and by Harold and Steele in Proceedings of Euro display 84, pages 29-31, September 1984, Paris, France, in which the material in the device was a smectic liquid crystal material. Devices which use a liquid crystal material as the  
25 optical storage medium are an important class of such devices. The use of semiconductor lasers, especially  $\text{Ga}_x\text{Al}_{1-x}\text{As}$  lasers where  $x$  is from 0 to 1, and is preferably 1, has proven popular in the above applications because they can provide laser energy at a range of wavelengths in the near infra-red which cannot be seen and thus cannot interfere with the visual display, and yet can provide a useful source of  
30 well-defined, intense heat energy. Gallium arsenide lasers provide laser light at wavelengths of about 850nm, and are useful for the above applications. With increasing Al content ( $x < 1$ ), the laser wavelength may be reduced down to about 750nm. The storage density can be increased by using a laser of shorter wavelength.



Thus some compounds of the present invention may be suitable as optical storage media and may be combined with dyes for use in laser addressed systems, for example in optical recording media.

The compounds of the present invention may also be used in pyroelectric devices for example detectors, steering arrays and vidicon cameras.

A pyroelectric detector consists of electrode plates at least one of which may be pixellated. In operation the detector is exposed to radiation R, for example infrared radiation, which is absorbed by an electrode. This results in a rise in temperature which is transmitted to a layer of pyroelectric material by conduction. The change in temperature results in a thermal expansion and a charge is generated. This change in charge is usually small when compared with the charge output due to the change in the spontaneous polarisation,  $P_s$  with a change in temperature; this constitutes the primary pyroelectric effect. A change in charge results in a change in potential difference between the electrodes. The charge on each pixel may be read out and the resulting signal is used to modulate scanning circuits in, for example, a video monitor and for a visual image of the infra red scans.

The selective reflective properties of the materials described by the current invention may also allow for materials of the current invention to be used in inks and paints and they may therefore be useful in anti-counterfeiting operation. They may also be used in so-called security inks. Other applications include thermal control management, for example the materials may be included in a coating which may be applied to one or more windows in order to reflect infra-red radiation.

Spatial light modulators comprises a liquid crystal cell formed by typically two glass walls and 0.1-10 $\mu$ m e.g. 2.5 $\mu$ m thick spacer. The inner faces of the walls carry thin transparent indium tin oxide electrodes connected to a variable voltage source. On top of the electrodes are surface alignment layers e.g. of rubbed polyimide described in detail later. Other alignment techniques are also suitable e.g. non-rubbing techniques such as evaporation of SiO<sub>2</sub>. A layer of liquid crystal material is contained between the walls and spacer. In front of the cell is a linear polariser; behind the cell is a quarter waveplate (this may be optional) and a mirror. An example of a linear polariser is a polarising beam splitter (not illustrated here).

Suitable devices in which the materials of the current invention may be incorporated include beam steerers, shutters, modulators and pyroelectric and piezoelectric sensors.

The materials of the present invention may also be useful as dopants in  
5 ferroelectric liquid crystal devices, which may be multiplexed, or they may be used in active backplane ferroelectric liquid crystal systems. The materials of the present invention may also be useful as host materials. The materials of the present invention may be included in mixtures which also contain one or more dopants.

The invention will now be particularly described by way of example.

10 **Example 1**

**Preparation of Compound 3 in Table 1**

**Step 1**

**Preparation of 1-Bromo-4-heptylbenzene**

Anhydrous aluminium chloride (19.8 g, 148 mmol) was added to a stirred  
15 solution of heptanoyl chloride (24.2 g, 163 mmol) in dry dichloromethane (135 ml). A solution of bromobenzene (21.2 g, 135 mmol) in dry dichloromethane (45 ml) was added, and the mixture was refluxed overnight with exclusion of moisture. The reaction was monitored by glc analysis. The mixture was cooled in an ice/water bath and poly(methylhydrosiloxane) (21.7 g, 360 mmol) was added dropwise with stirring.  
20 The mixture was refluxed overnight, glc analysis indicating complete conversion of the ketone. After removal of the solvent *in vacuo* the residue was poured into an ice/water mixture and sodium hydroxide solution (10%) was added to facilitate layer separation and to remove residual acid chloride. Ether was added and the separated aqueous layer was washed with ether (2 x 200 ml). The combined organic layers were washed with  
25 sodium hydroxide solution (10%), water and brine, and dried (MgSO<sub>4</sub>). Removal of the solvent *in vacuo* gave a residue which was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by distillation *in vacuo*.  
A colourless oil was obtained.

Yield 15.1 g (44%) bp 117 °C at 0.1 mm Hg

30 <sup>1</sup>H NMR CDCl<sub>3</sub>/δ      7.38 (2H, d), 7.04 (2H, d), 2.54 (2H, t),  
1.57 (2H, qui) 1.28 (8H, m), 0.88 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>      2930, 1490, 1073, 828, 799

**MS *m/z*** 256,254( $M^+$ ), 199, 185, 171(100%), 90

## **Step 2**

### **Preparation of 4-Heptylbenzeneboronic acid**

1-Bromo-4-heptylbenzene from step 1 (20.0 g, 78 mmol) in dry  
5 tetrahydrofuran(80 ml) was added in one portion to oven-dried magnesium (2.2 g, 90  
mmol) in dry tetrahydrofuran (100 ml) with stirring under nitrogen. A crystal of iodine  
was added, and the mixture refluxed (2.5 h) and then allowed to return to room  
temperature. Dry tetrahydrofuran (80 ml) was added and the mixture cooled to -40 °C.  
Trimethyl borate (16.21 g, 156 mmol) was added dropwise, keeping the temperature  
10 below -10 °C. The mixture was allowed to return to room temperature and  
hydrochloric acid (5M, 36 ml) was added whilst stirring (45 min). The mixture was  
then poured into water and ether added. The separated aqueous layer was washed  
twice with ether (2 x 200 ml), and the product was extracted from the combined  
ethereal phases as the sodium salt by washing with potassium hydroxide (2M, 40 ml),  
15 The basic solution was then washed with ether, and the product released by  
acidification to pH3 by adding hydrochloric acid (conc.) to the aqueous solution. The  
product was then extracted with ether (2 x 200 ml), which was washed with water and  
brine, dried ( $MgSO_4$ ), and the solvent removed *in vacuo*.

A pale-brown solid was obtained.

20 Yield 15.8 g (92%).

**MS *m/z*** 220( $M^+$ ), 192, 135, 122, 107(100%)

## **Step 3**

### **Preparation of Ethyl 5-bromobenzo[b]furan-2-carboxylate**

A mixture of 5-bromosalicylaldehyde (2.0 g, 10 mmol), diethyl bromomalonate  
25 (2.0 g, 8.4 mmol), and potassium carbonate (2.5 g, 18 mmol) was refluxed in butanone  
(30 ml) (7 h). Glc analysis revealed no further reaction. When cool, the solvent was  
removed *in vacuo*, and water and dichloromethane added. The separated aqueous  
layer was washed twice with dichloromethane (2 x 100 ml) and the combined organic  
layers dried ( $MgSO_4$ ). After removal of the solvent *in vacuo* the residue was  
30 recrystallised (ethanol).

Pale yellow needle-like crystals were obtained.

Yield 0.9 g (40%), mp 58-60 °C.

**<sup>1</sup>H NMR** CDCl<sub>3</sub>/δ      7.82 (1H, d), 7.54 (1H, dd), 7.47 (1H, d),  
    7.46 (1H, s), 4.46 (2H, q), 1.43 (3H, t)  
**IR** (KBr) ν<sub>max</sub>/cm<sup>-1</sup>      1730, 1555, 1310, 1185, 855  
**MS** *m/z*                      268, 270(M<sup>+</sup>), 240, 225(100%), 196, 169

5    **Step 4**

**Preparation of Ethyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate**

Ethyl 5-bromobenzo[b]furan-2-carboxylate (2.0 g, 7.4 mmol) from step 3, sodium carbonate (2.0 g, 18.5 mmol), 1,2-dimethoxyethane (10 ml) and water (30 ml), were stirred under nitrogen. Tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3  
 10 mmol) was added, followed by 4-heptylbenzeneboronic acid from step 2 (2.0 g, 8.9 mmol) in 1,2-dimethoxyethane (20 ml), and the mixture refluxed (4 h). Completion of the reaction was indicated by glc and tlc analysis. After allowing to cool, the reaction mixture was poured into water and ether added. The separated aqueous layer was washed with ether (2 x 100 ml), and the combined ethereal layers washed with water  
 15 and brine and dried (MgSO<sub>4</sub>). After removal of the solvent *in vacuo* the residue was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C) (impurity); petroleum fraction (bp 40-60 °C), dichloromethane 7:3 (product)]. The product was recrystallised (hexane).  
 Colourless needles were obtained.  
 20            Yield 1.3 g (48%), mp 46-8 °C.

**<sup>1</sup>H NMR** CDCl<sub>3</sub>/δ      7.84 (1H, dd), 7.67 (1H, dd), 7.63 (1H, d),  
    7.56 (1H, d), 7.52 (2H, d), 7.27 (2H, d), 4.46 (2H, q), 2.65  
    (2H, t), 1.65 (2H, qui), 1.44 (3H, t), 1.33 (8H, m), 0.89 (3H,  
    t)  
 25    **IR** (KBr) ν<sub>max</sub>/cm<sup>-1</sup>      2930, 1725, 1560, 1160, 1095  
**MS** *m/z*                      364(M<sup>+</sup>)(100%), 279, 264, 251, 220

**Step 5**

**Preparation of 5-(4-Heptylphenyl)benzo[b]furan-2-carboxylic acid**

Potassium hydroxide (0.5 g, 6.8 mmol) in ethanol (30 ml) and water (3 ml) was  
 30 added to ethyl 5-(4-heptylphenyl)benzo{b} furan-2-carboxylate from step 4 (1.2 g, 3.4 mmol).and the mixture was refluxed (5 min) with stirring. The solvent was then

removed *in vacuo* and water added to the residue, which was then adjusted to pH 3 by adding hydrochloric acid (2M). The precipitated white solid was then filtered off and dried *in vacuo* (CaCl<sub>2</sub>), and recrystallised (acetic acid).

White, fibrous needles were obtained.

5 Yield 0.7 g (63%).

Transitions (°C) K 131 SmC 185 N 222 Iso.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.88 (1H, dd), 7.74 (1H, dd), 7.74 (1H, d),  
7.67 (1H, d), 7.54 (2H, d), 7.28 (2H, d),  
7.27 (1H, s), 2.66 (2H, t), 1.65 (2H, qui),  
1.33 (8H, m), 0.89 (3H, m)

10

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2950, 2850, 1690, 1575, 1310, 1170, 805

MS m/z 336(M<sup>+</sup>), 292, 251(100%), 231, 207

#### Step 6

#### Preparation of 5-(4-heptylphenyl)benzo[b]furan-2-carboxamide

15 A mixture of 5-(4-heptylphenyl)benzo[b]furan-2-carboxylic acid from step 5 (0.70 g, 2.1 mmol) and thionyl chloride (0.75 g, 6.3 mmol) in dry benzene (25 ml) was refluxed (4 h) with exclusion of moisture. The solvent was then removed *in vacuo*, and the crude acid chloride dissolved in dry tetrahydrofuran (20 ml). Ammonia (d 0.880, 0.7 ml) was then added with stirring. After stirring for a further 30 min, water  
20 (40 ml) was added and the precipitate filtered off and washed with cold water. It was then recrystallised (ethanol), and dried *in vacuo* overnight (CaCl<sub>2</sub>).

White crystals were obtained.

Yield 0.55 g (78%), mp 201-2 °C.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.86 (1H, dd), 7.66 (1H, dd), 7.56 (1H, d),  
25 7.56 (1H, d) 7.53 (2h, d), 7.27 (2H, d),  
6.54 (1H, s), 5.65 (1H, s) 2.66 (2H, t),  
1.66 (2H, qui), 1.31 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3471, 3396, 3183, 2922, 2849, 1661, 1616,  
1395, 801

30 MS m/z 335(M<sup>+</sup>), 250(100%), 191, 178, 165

**Step 7****Preparation of 2-Cyano-5-(4-heptylphenyl)benzo[b]furan (Compound 3)**

Thionyl chloride (1.8 g, 15 mmol) was added to a stirred solution of 5-(4-heptylphenyl)benzo[b]furan-2-carboxamide (0.5 g, 1.5 mmol) from step 6 in dry *N,N*-dimethylformamide (10 ml) under nitrogen. The mixture was stirred overnight, and then poured into an ice/water mixture. The product was extracted with ether (2 x 100 ml), and the combined extractions were washed with water and saturated sodium bicarbonate solution and dried (MgSO<sub>4</sub>). The solvent was removed *in vacuo* and the product purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C), dichloromethane 1:1], followed by recrystallization (ethanol). Colourless crystals were obtained.

Yield 0.3 g (63%). Purity (hplc) >99%.

Transitions (°C) K 31.1 N 60.5 Iso.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.83 (1H, d), 7.73 (1H, dd), 7.60 (1H, d),  
7.51 (2H, d), 7.50 (1H, s), 7.28 (2H, d),  
2.66 (2H, t), 1.65 (2H, qui), 1.33 (8H, m),  
0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2920, 2850, 2230, 1460, 1130, 885, 800

MS *m/z* 317(M<sup>+</sup>), 232(100%), 203, 190, 176

**Example 2****Preparation of Compound No. 25 in Table 1****Step 1****Preparation of 5-Bromobenzo[b]furan-2-carboxylic acid**

The title compound was prepared and purified in a similar manner to that described in Example 1 step 5 but using as starting material, ethyl 5-bromobenzo{b}furan-2-carboxylate (prepared as described in Example 1 step 3) (27.5 g, 102 mmol), potassium hydroxide (11.5 g, 204 mmol). White crystals were obtained.

Yield 16.6 g (68%), mp >290 °C.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.80 (1H, dd), 7.49 (1H, dd), 7.44 (1H, d),  
7.38 (1H, d)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3417, 1738, 1556, 1395, 1051, 946, 873, 803, 779

MS  $m/z$  241( $M^+$ ), 223, 169, 89, 62(100%)

### **Step 2**

#### **Preparation of 5-Bromobenzo[b]furan-2-carboxamide**

- 5 5-Bromobenzo[b]furan-2-carboxylic acid from step 1 (16.5 g, 69 mmol), thionyl chloride (24.4 g, 205 mmol), ammonia (d 0.880, 46 ml) was converted to 5-bromobenzo[b]furan-2-carboxamide using a method analogous to that described in Example 1 step 6.

White needles were obtained.

- 10 Yield 9.9 g (60%), mp 212-215 °C.

$^1\text{H}$  NMR DMSO- $d^6/\delta$  7.80 (1H, d), 7.51 (1H, d), 7.40 (1H, dd),  
7.32 (2H, s), 6.95 (1H, d)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3024, 2860, 1591, 1563, 1473, 1318, 1179,  
789, 422

- 15 MS  $m/z$  240( $M^+$ ), 223, 169, 89, 62(100%)

### **Step 3**

#### **Preparation of 2-Cyano-5-bromobenzo[b]furan**

- 5-Bromobenzo[b]furan-2-carboxamide (9.8 g, 41 mmol) prepared as described in step 2, thionyl chloride (49.2 g, 410 mmol) were reacted using a method analogous to that described above in Example 1 step 7 to yield 2-Cyano-5-bromobenzo[b]furan. Off-white needles were obtained.

Yield 4.6 g (51%), mp 152.5-153.5 °C.

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.86 (1H, dd), 7.63 (1H, dd), 7.47 (1H, dd),  
7.46 (1H, d)

- 25 IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2230, 1552, 1437, 1183, 949, 810, 571, 478

MS  $m/z$  223, 221( $M^+$ )(100%), 142, 114, 87, 58

### **Step 4**

#### **Preparation of 1-Bromo-4-propylbenzene**

- Bromobenzene (31.4 g, 200 mmol), propionyl chloride (22.2 g, 240 mmol),  
30 aluminium chloride (29.5 g, 220 mmol), poly(methylhydrosiloxane) (32.1 g 533

mmol) were converted to 1-bromo-4-propylbenzene using a method analogous to that described in Example 1 step 1.

A colourless liquid was obtained.

Yield 19.2 g (48%), bp 115 °C at 0.03 mm Hg.

5  $^1\text{H NMR}$   $\text{CDCl}_3/\delta$  7.38 (2H, d), 7.05 (2H, d), 2.51 (2H, t),  
1.61 (2H, sxt), 0.92 (3H, t)

$\text{IR (KBr)} \nu_{\text{max}}/\text{cm}^{-1}$  2965, 2871, 1489, 1077, 1011, 828, 796

$\text{MS } m/z$  200, 198( $\text{M}^+$ ), 169(100%), 119, 103, 90

### Step 5

#### 10 Preparation of 4-Propylbenzeneboronic acid

1-Bromo-4-propylbenzene (11.0 g, 55 mmol) obtained in step 2, magnesium (1.5 g, 61 mmol), trimethyl borate (11.4 g, 110 mmol) were reacted using a method analogous to that described in Example 1 step 2. An off-white solid was obtained.

Yield 7.5 g (83%).

15  $\text{MS } m/z$  164( $\text{M}^+$ ), 147, 135, 91, 43(100%)

### Step 6

#### Preparation of 2-Cyano-5-(4-propylphenyl)benzo[b]furan (Compound 25 in Table 1)

20 2-Cyano-5-bromobenzo{b}furan obtained as described in step 3 above (1.0 g, 4.5 mmol), 4-propylbenzene boronic acid obtained as described in step 5 above (0.9 g, 5.4 mmol), sodium carbonate (1.2 g, 11.3 mmol), tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol) were reacted using a method analogous to that described in Example 1 step 4 to yield compound 25 in table 1 as white crystals.

25 Yield 0.3 g (26%). Purity (hplc) >99%.

Transitions (°C) K 58.0 (48.9 N) Iso.

$^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.86 (1H, dd), 7.75 (1H, dd), 7.62 (1H, d),  
7.55 (1H, d), 7.52 (2H, d), 7.29 (2H, d),  
2.64 (2H, t), 1.67 (2H, sxt), 0.97 (3H, t)

30  $\text{IR (KBr)} \nu_{\text{max}}/\text{cm}^{-1}$  2962, 2871, 2229, 1560, 1460, 1266, 1126,  
885, 801, 612



**MS *m/z*** 261( $M^+$ ), 232(100%), 203, 176, 151

**Example 3**

**Preparation of Compound 26 in Table 1**

**Step 1**

5 **Preparation of 1-Bromo-4-pentylbenzene**

Bromobenzene (21.2 g, 135 mmol), valeryl chloride (19.7 g, 163 mmol), aluminium chloride (19.8 g, 148 mmol), poly(methylhydrosiloxane) (21.7 g, 360 mmol) were reacted using a method analogous to that described in Example 1 step 1 to yield 1-bromo-4-pentylbenzene as a colourless liquid .

10 Yield 11.6 g (38%) bp 100 °C at 0.2 mm Hg.

**$^1\text{H}$  NMR  $\text{CDCl}_3/\delta$**  7.38 (2H, d), 7.04 (2H, d), 2.54 (2H, t),  
1.58 (2H, qui), 1.31 (4H, m), 0.88 (3H, t)

**IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$**  2929, 2858, 1486, 1073, 830, 796

**MS *m/z*** 228,226( $M^+$ ), 198, 183, 171(100%), 157

15 **Step 2**

**Preparation of 4-Pentylbenzeneboronic acid**

Using a method analogous to that described in Example 1 step 2, the title compound was obtained from 1-bromo-4-pentylbenzene from Step 1 (15.2 g, 67 mmol), magnesium (1.9 g, 77 mmol), and trimethyl borate (13.9 g, 134 mmol). The  
20 product was obtained as a waxy white solid.

Yield 6.4 g (50%).

**MS *m/z*** 522( $3M^+-3\text{H}_2\text{O}$ ), 465(100%), 409, 352, 175

**Step 3**

**Preparation of 2-Cyano-5-(4-pentylphenyl)benzo[b]furan (Compound 26 in Table**

25 **1)**

2-Cyano-5-bromobenzo[b]furan obtained as described in Example 2 step 3 (0.6 g, 2.7 mmol), 4-pentylbenzeneboronic acid from step 2 above (0.6 g, 3.2 mmol), sodium carbonate (0.7 g, 6.8 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.1 mmol) were reacted together in a method analogous to that described in Example 1  
30 step 4 to give the desired compound as colourless plates.

Yield 0.3 g (38%). Purity (hplc) >99%.

Transitions (°C) K 51.1 N 56.4 Iso.

	<b><sup>1</sup>H NMR</b> CD <sub>2</sub> Cl <sub>2</sub> /δ	7.87 (1H, dd), 7.75 (1H, dd), 7.61 (1H, ddd), 7.54 (1H, d), 7.52 (2H, d), 7.28 (2H, d), 2.66 (2H, t), 1.65 (2H, qui), 1.34 (4H, m), 0.91 (3H, t)
5	<b>IR</b> (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2965, 2861, 2232, 1558, 1439, 1187, 949, 819, 524
	<b>MS</b> m/z	289(M <sup>+</sup> ), 232(100%), 203, 189, 176

**Example 4****Preparation of Compound 40 in Table 1**10 **Step 1****Preparation of 1-Bromo-4-hexylbenzene**

1-Bromo-4-hexylbenzene was prepared and purified using a method analogous to that described in Example 1 step 1 but using as starting materials, bromobenzene (21.2 g, 135 mmol), hexanoyl chloride (20.0 g, 149 mmol), aluminium chloride (19.9 g, 149 mmol), and poly(methylhydrosiloxane) (21.7 g, 360 mmol).  
A colourless liquid was obtained.

Yield 10.4 g (32%), bp 110 °C at 0.01 mm Hg.

	<b><sup>1</sup>H NMR</b> CDCl <sub>3</sub> /δ	7.38 (2H, d), 7.03 (2H, d), 2.54 (2H, t), 1.57 (2H, qui), 1.29 (6H, m), 0.88 (3H, t)
20	<b>IR</b> (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2933, 2861, 1489, 1075, 807, 525
	<b>MS</b> m/z	242,240(M <sup>+</sup> ), 171(100%), 103, 91

**Step 2****Preparation of 4-Hexylbenzeneboronic acid**

4-Hexylbenzeneboronic acid was obtained from the product of step 1 (8.0 g, 33 mmol), magnesium (1.0 g, 40 mmol), and trimethyl borate (6.9 g, 66 mmol) using a method analogous to that described in Example 1 step 2.  
A light-brown solid was obtained.

Yield 4.8 g (71%).

	<b>MS</b> m/z	564(3M <sup>+</sup> -3H <sub>2</sub> O), 535, 507, 493, 117(100%)
--	---------------	---

**Step 3****Preparation of 2-Cyano-5-(4-hexylphenyl)benzo[b]furan (Compound 40 in Table 1)**

2-Cyano-5-bromobenzo[b]furan obtained as described in Example 2 step 3 (1.0 g, 4.5 mmol), 4-hexylbenzeneboronic acid (obtained as described in step 2 above) (1.0 g, 5 mmol), sodium carbonate (1.2 g, 11 mmol) and tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol) were reacted together in a method analogous to that described in Example 1 step 4. Compound 40 in Table 1 was obtained as colourless crystals.

Yield 0.3 g (22%).

Purity (hplc) 99%.

Transitions (°C) K 25.4 N 45.2 Iso.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.83 (1H, d), 7.73 (1H, dd), 7.60 (1H, d), 7.51 (2H, d), 7.49 (1H, s), 7.28 (2H, d), 2.66 (2H, t), 1.66 (2H, qui), 1.39-1.31 (6H, m), 0.90 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2933, 2861, 2235, 1561, 1271, 1128, 951, 808

MS *m/z* 303(M<sup>+</sup>), 274, 246, 232(100%), 219

**Example 5****Preparation of Compound 36 in Table 1****Step 1****Preparation of 1-Bromo-4-octylbenzene**

The title was prepared and purified using a method analogous to that described in Example 1 step 1 but using the following starting materials:  
Bromobenzene (21.2 g, 135 mmol), nonanoyl chloride (24.2 g, 149 mmol), aluminium chloride (19.9 g, 149 mmol), poly(methylhydrosiloxane) (21.7 g, 360 mmol).  
A colourless liquid was obtained.

Yield 16.4 g (45%), bp 158 °C at 0.9 mm Hg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.37 (2H, d), 7.06 (2H, d), 2.54 (2H, t), 1.56 (2H, qui), 1.26 (10H, m), 0.86 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2932, 2859, 1489, 1074, 803, 519

**MS  $m/z$**  270,268( $M^+$ ), 211, 169(100%), 155, 89

## **Step 2**

### **Preparation of 4-Octylbenzeneboronic acid**

4-Octylbenzeneboronic acid was prepared and purified using a method analogous to that described in Example 1 step 2 using the following materials:  
 1-Bromo-4-octylbenzene from step 1 (6.0 g, 22 mmol), magnesium (0.7 g, 27 mmol), trimethyl borate (4.6 g, 44 mmol).  
 A pale-yellow solid was obtained.

Yield 4.2 g (82%).

10 **MS  $m/z$**  648( $3M^+ - 3H_2O$ ), (100%), 551, 452, 353, 187

## **Step 3**

### **Preparation of 2-Cyano-5-(4-octylphenyl)benzo[b]furan (Compound 36 in Table 1)**

Compound 36 was prepared and purified in a similar manner to that described in Example 1 step 4 from the following materials:  
 4-octylbenzeneboronic acid from step 2 (2.0 g, 8.5 mmol), 2-cyano-5-bromobenzo[b]furan (obtained as described in Example 2 step 3) (1.6 g, 7.1 mmol), sodium carbonate (1.9 g, 18 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol)

20 A colourless liquid crystal was obtained.

Yield 0.5 g (21%).

Purity (hplc) 98.5%.

Transitions ( $^{\circ}\text{C}$ ) K 28.2 SmA 34.3 N 48.8 Iso.

25  **$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$**  7.87 (1H, dd), 7.45 (1H, dd), 7.62 (1H, d),  
 7.55 (1H, d), 7.53 (2H, d), 7.29 (2H, d),  
 2.66 (2H, t), 1.65 (2H, qui), 1.35-1.29  
 (10H, m), 0.89 (3H, t)

**IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$**  2932, 2859, 2235, 1561, 1464, 1184, 951, 807

**MS  $m/z$**  331( $M^+$ ), 260, 232(100%), 203, 57

**Example 6****Preparation of Compound 34 in Table 1****Step 1****Preparation of 1-Bromo-4-nonylbenzene**

5           The title compound was prepared and purified in a similar manner to that described in Example 1 step 1 from the following reagents:  
Bromobenzene (21.2 g, 135 mmol), nonanoyl chloride (26.3 g, 149 mmol), aluminium chloride (19.9 g, 149 mmol), poly(methylhydrosiloxane) (21.7 g, 360 mmol).  
A colourless liquid was obtained, which solidified to a waxy solid on standing.

10           Yield 7.0 g (18%), bp 145 °C at 0.01 mm Hg.

$^1\text{H NMR}$   $\text{CDCl}_3/\delta$            7.38 (2H, d), 7.04 (2H, d), 2.54 (2H, t),  
1.58 (2H, qui), 1.27 (12H, m), 0.88 (3H, t)

$\text{IR}$  (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$        2934, 2859, 1490, 1074, 825, 798, 634, 510

$\text{MS } m/z$                        284, 282( $\text{M}^+$ ), 169, 91(100%), 71

15   **Step 2**

**Preparation of 4-Nonylbenzeneboronic acid**

          The title compound was prepared and purified in a similar manner to that described in Example 1 step using the following reagents:  
1-Bromo-4-nonylbenzene from step 1 (5.0 g, 18 mmol), magnesium (0.5 g, 22 mmol),  
20   trimethyl borate (3.7 g, 36 mmol).  
A waxy white solid was obtained.  
Yield 3.7 g (83%).

$\text{MS } m/z$                        691( $3\text{M}^+-3\text{H}_2\text{O}$ ), 578, 452, 354, 117(100%)

**Step 3**

25   **Preparation of 2-Cyano-5-(4-nonylphenyl)benzo[b]furan (Compound 34 in Table 1)**

          Compound 34 was prepared and purified in a similar manner to that described in Example 1 step 4 from the following reagents:  
4-nonylbenzeneboronic acid from step 2 (1.2 g, 5 mmol), 2-cyano-5-  
30   bromobenzo[b]furan (obtained as described in Example 2 step 3) (1.0 g, 4.5 mmol), sodium carbonate (1.2 g, 11 mmol), tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol)

Colourless needles were obtained.

Yield 0.5 g (32%).

Purity (hplc) 98.6%.

Transitions (°C) K 28.1 SmA 49.6 N 60.0 Iso.

5	<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.86 (1H, dd), 7.75 (1H, dd), 7.61 (1H, d), 7.55 (1H, d), 7.52 (2H, d), 7.29 (2H, d), 2.66 (2H, t), 1.65 (2H, qui), 1.31 (12H, m), 0.89 (3H, t)
	IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2929, 2858, 2333, 1464, 1127, 950, 887, 805
	MS m/z	345(M <sup>+</sup> ), 231(100%) 218, 190, 176

10 **Example 7**

**Preparation of Compound 16 in Table 1**

**Step 1**

**Preparation of 4-Nonyloxybenzeneboronic acid**

The title compound was prepared and purified in a similar manner to that described in Example 1 step 2 using the following reagents:

15 4-Nonyloxybromobenzene (5.0 g, 17 mmol), magnesium (0.5 g, 22 mmol), trimethyl borate (3.5 g, 34 mmol).

A pale yellow solid was obtained.

Yield 4.0 g (88%).

20	MS m/z	264(M <sup>+</sup> ), 238, 220, 151, 94(100%)
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**Step 2**

**Preparation of Ethyl 5-(4'-nonyloxyphenyl)benzo[b]furan-2-carboxylate**

Ethyl 5-bromobenzo[b]furan-2-carboxylate (obtained as described in Example 1 step 3) (1.5 g, 14 mmol), 4-nonyloxybenzeneboronic acid (1.8 g, 7 mmol), sodium carbonate (1.5 g, 14 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2

25 mmol) were reacted together using a method analogous to that described in Example 1 step 4. Ethyl 5-(4'-nonyloxyphenyl)benzo[b]furan-2-carboxylate was obtained as a white solid.

Yield 0.7 g (31%).

30 Transitions (°C) K 85.8 (84.6 SmA) Iso.

	<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.83 (1H, d), 7.66 (1H, dd), 7.62 (1H, d), 7.55 (1H, s), 7.54 (2H, d), 6.98 (2H, d),
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	4.41 (2H, q), 4.00 (2H, t), 1.80 (2H, qui),
	1.41 (2H, t), 1.30 (12H, m), 0.89 (3H, t)
<b>IR</b> (KBr) $\nu_{\max}/\text{cm}^{-1}$	2923, 2852, 1722, 1607, 1574, 1517, 1164,
	945, 839, 747
5 <b>MS</b> $m/z$	408( $M^+$ ), 281, 227, 97, 57(100%)

**Step 3****Preparation of 5-(4-Nonyloxyphenyl)benzo[b]furan-2-carboxylic acid**

5-(4-Nonyloxyphenyl)benzo[b]furan-2-carboxylic acid  
 was prepared and purified in a similar manner to that described in Example 1 step 5  
 10 using the following reagents:  
 Ethyl 5-(4'-nonyloxyphenyl)benzo[b]furan-2-carboxylate from step 2(0.7 g, 1.7  
 mmol), potassium hydroxide (0.2 g, 3.4 mmol).

A white crystalline solid was obtained.

Yield 0.5 g (77%).

15 Transitions (°C) K 212.2 SmC 223.0 Iso.

<b><math>^1\text{H}</math> NMR</b> $\text{CD}_2\text{Cl}_2/\delta$	7.87 (1H, d), 7.72 (1H, dd), 7.69 (1H, s),
	7.65 (1H, d), 7.54 (2H, d), 6.99 (2H, d),
	4.01 (2H, t), 1.80 (2H, qui), 1.48 (2H, m),
	1.30 (10H, m), 0.89 (3H, t)
20 <b>IR</b> (KBr) $\nu_{\max}/\text{cm}^{-1}$	3420, 2920, 2840, 2547, 1690, 1515, 1174,
	942, 748
<b>MS</b> $m/z$	380( $M^+$ ), 254(100%) 225, 210, 180

**Step 4****Preparation of 5-(4-Nonyloxyphenyl)benzo[b]furan-2-carboxamide**

25 The product of step 3 (0.9 g, 2.4 mmol), thionyl chloride (0.9 g, 7.2 mmol), and  
 ammonia (d 0.880, 1.4 ml) were used in a method analogous to that described in  
 Example 1 step 6 to yield the desired compound as a white crystalline solid.

Yield 0.8 g (82%), mp 201-202 °C.

<b><math>^1\text{H}</math> NMR</b> $\text{CD}_2\text{Cl}_2/\delta$	7.83 (1H, dd), 7.65 (1H, dd), 7.57 (1H, d),
30	7.54 (2H, d), 7.49 (1H, d), 6.99 (2H, d),
	6.53 (1H, s), 5.65 (1H, s), 4.00 (2H, t),

1.80 (2H, qui), 1.41 (12H, m), 0.88 (3H, t)  
 IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3462, 2919, 2851, 1678, 1601, 1518, 1166,  
 941, 812  
 MS  $m/z$  379( $M^+$ ), 253(100%) 225, 181, 152

5 **Step 5**

**Preparation of 2-Cyano-5-(4-nonyloxyphenyl)benzo[b]furan (Compound 16 in Table 1)**

Compound 16 was prepared and purified in a similar manner to that described in Example 1 step 7 using the quantities stated.

10 The product of step 4 (0.7 g, 1.9 mmol), thionyl chloride (2.3 g, 19 mmol).  
 Colourless plate-like crystals were obtained.

Yield 0.1 g (15%).

Purity (hplc) 99.9%.

Transitions ( $^{\circ}\text{C}$ ) K 62 SmA 87 N 97 Iso

15  $^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.80 (1H, d), 7.70 (1H, dd), 1.58 (1H, d),  
 7.52 (1H, s), 7.51 (2H, d), 6.97 (2H, d),  
 3.98 (2H, t), 1.78 (2H, qui), 1.46 (2H, m),  
 1.28 (10H, m), 0.87 (3H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2930, 2859, 2236, 1688, 1517, 1182, 1032,  
 20 842, 808

MS  $m/z$  361( $M^+$ ), 248, 235(100%), 206

**Example 8**

**Preparation of Compound 41 in Table 1**

**Step 1**

25 **Preparation of 2-(4-(4-Pentylcyclohexyl)phenoxy)acetaldehyde dimethyl acetal**

A mixture of 4-(4-pentylcyclohexyl)phenol (10.0 g, 41 mmol),  
 bromoacetaldehyde dimethyl acetal (10.1 g, 60 mmol), potassium carbonate (11.1 g,  
 80 mmol) and potassium iodide (0.5 g, 3 mmol) in cyclopentanone (60 ml) was  
 refluxed under nitrogen with stirring (48 h). The reaction was monitored by glc  
 30 analysis. After allowing to cool, the mixture was poured into water and ether added.  
 The separated aqueous phase was saturated with salt and washed with ether 2 x 200  
 ml). The combined organic layers were washed with sodium hydroxide solution



(10%), water, dried (Na<sub>2</sub>SO<sub>4</sub>), and the solvent removed *in vacuo*. The crude product was purified by flash chromatography [neutral alumina / petroleum fraction (bp 40-60 °C), dichloromethane 1:1].

A pale yellow liquid was obtained.

5           Yield 10.1 g (75%), bp 195 °C at 0.01 mm Hg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ       7.11 (2H, d), 6.82 (2H, d), 4.66 (1H, t),  
3.94 (2H, d), 3.41 (6H, s), 2.83-2.80 (1H, m),  
1.73-1.66 (4H, m), 1.45-1.38 (1H, m),  
1.35-1.20 (10H, m), 1.08-1.02 (2H, m), 0.89  
10                           (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>   2928, 2860, 1709, 1644, 1514, 1139, 1081,  
828

MS *m/z*               334(M<sup>+</sup>), 260, 176, 133, 75(100%)

## Step 2

### 15   Preparation of 5-(4-Pentylcyclohexyl)benzo[b]furan

The product of step 1 (10.1 g, 31 mmol) was added dropwise to polyphosphoric acid (13 g) in chlorobenzene (130 ml) under reflux with stirring. The mixture was refluxed overnight (glc analysis indicated a complete reaction), and allowed to cool. The solvent was removed *in vacuo* and sodium hydroxide solution (10%) and ether  
20   were added. The separated aqueous layer was washed with ether (2 x 200 ml) and the combined organic layers washed with water and brine, and dried (MgSO<sub>4</sub>). The solvent was removed *in vacuo* and the crude product purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by distillation.

A pale-yellow liquid was obtained.

25           Yield 4.1 g (48%), bp 165 °C at 0.01 mm Hg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ       7.76 (1H, d), 7.34 (1H, d), 7.31 (1H, d),  
7.07 (1H, dd), 6.64 (1H, dd), 2.48 (1H, tt),  
1.84-1.77 (4H, m), 1.44 (1H, dd), 1.38 (1H, dd), 1.26-1.14 (9H, m), 1.02 (1H, dd), 0.95  
30                           (1H, dd), 0.83 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>   2927, 2856, 1514, 1455, 1197, 877, 809, 735

**MS  $m/z$**  270( $M^+$ ), 199, 171, 157(100%), 131

### **Step 3**

#### **Preparation of 5-(4-Pentylcyclohexyl)benzo[b]furan-2-carboxylic acid**

A flask containing the product of step 2 (1.7 g, 6.3 mmol) in dry  
 5 tetrahydrofuran (70 ml) was flushed with nitrogen, degassed, flushed again with  
 nitrogen and cooled (-70 °C). n-Butyllithium (2.5M in hexanes, 2.7 ml, 6.7 mmol) was  
 then added dropwise with stirring, which was continued (0.5 h) at -70 °C. The mixture  
 was then poured into a stirred slurry of 'Cardice' in dry tetrahydrofuran, and allowed  
 to return to room temperature with continuous stirring. The solvent was removed *in*  
 10 *vacuo*. The residue was dissolved in glacial acetic acid and the resulting solution was  
 poured into water. The solid was filtered off, washed with water and dried *in vacuo*  
 (KOH).

A white solid was obtained.

Yield 0.2 g (10%).

15  **$^1\text{H}$  NMR**  $\text{CD}_2\text{Cl}_2/\delta$  7.47 (1H, d), 7.44(1H, d), 7.39 (1H, s),  
 7.27 (1H, dd), 2.54 (1H, tt), 1.89-1.83 (4H,  
 m), 1.49 (1H, dd), 1.42 (1H, dd), 1.31-1.19  
 (9H, m), 1.07 (1H, dd), 1.10 (1H, dd), 0.86  
 (3H, t)  
 20 (acidic proton signal was not shown)  
**IR** (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  3100, 2926, 2853, 1692, 1580, 1425, 943, 828  
**MS  $m/z$**  314( $M^+$ ), 260, 201, 188(100%), 175

### **Step 4**

#### **Preparation of 5-(4-Pentylcyclohexyl)benzo[b]furan-2-carboxamide**

25 The title compound was prepared and purified in a similar manner to that  
 described in Example 1 step 6 using the following reagents:  
 The product of step 3 (0.2 g, 0.6 mmol), thionyl chloride (0.2 g, 1.8 mmol), ammonia  
 (d 0.880, 0.4 ml).  
 Colourless needle-like crystals were obtained.  
 30 Yield 0.08 g (50%), mp 214-215 °C

**$^1\text{H}$  NMR**  $\text{CD}_2\text{Cl}_2/\delta$  7.51 (1H, d), 7.43 (1H, d), 7.41 (1H, d),  
 7.31 (1H, dd), 6.51 (1H, s, br), 5.69 (1H,

s, br), 2.59 (1H, tt), 1.93-1.88 (4H, m),  
1.55-1.45 (2H, m), 1.33-1.21 (9H, m), 1.36-  
1.03 (2H, m), 0.90 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3424, 3167, 2926, 2854, 1659, 1613, 1449,  
1198, 939, 888

**MS**  $m/z$  313( $M^+$ ), 200, 187(100%), 187, 115

### **Step 5**

#### **Preparation of 2-Cyano-5-(4-pentylcyclohexyl)benzo[b]furan (Compound 41 in Table 1)**

Compound 41 was prepared and purified in a similar manner to that described in Example 1 step 7 using the following reagents:

5-(4-pentylcyclohexyl)benzo[b]furan-2-carboxamide from step 4 (0.05 g, 0.2 mmol), thionyl chloride (0.2 g, 1.4 mmol).

A white solid was obtained.

Yield 0.03 g (60%).

Purity (hplc) >99%.

Transitions ( $^{\circ}\text{C}$ ) K 77.6 (N 58.5) Iso.

**$^1\text{H}$  NMR**  $\text{CD}_2\text{Cl}_2/\delta$  7.51 (1H, dd), 7.47 (1H, ddd), 7.45 (1H, d),  
7.39 (1H, dd), 2.60 (1H, tt), 1.93-1.87 (4H,  
m), 1.52-1.43 (2H, m), 1.33-1.21 (9H, m),  
1.14-1.03 (2H, m), 0.90 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2924, 2852, 2230, 1557, 1465, 1198, 950,  
874, 845, 815

**MS**  $m/z$  295( $M^+$ ), 252, 224, 182, 169(100%)

### **Example 9**

#### **Preparation of Compound 42 in Table 1**

##### **Step 1**

##### **Preparation of 2-(4-Bromophenoxy)acetaldehyde dimethyl acetal**

A mixture of 4-bromophenol (87.2 g, 504 mmol), bromoacetaldehyde dimethyl acetal (85.2 g, 520 mmol), potassium carbonate (71.9 g, 520 mmol) and potassium iodide (4.2 g, 25 mmol) in butanone (500 ml) was refluxed under nitrogen with stirring (48 h). The reaction was monitored by glc analysis. After allowing to cool, the

mixture was poured into water and ether added. The separated aqueous phase was saturated with salt and washed with ether (3 x 300 ml). The combined organic layers were washed with sodium hydroxide solution (10%), and water, dried (Na<sub>2</sub>SO<sub>4</sub>), and the solvent removed *in vacuo*. The crude product was then purified by flash chromatography [neutral alumina / dichloromethane], and distillation.

Yield 52.6 g (40%), bp 105 °C at 0.25 mm Hg.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ        7.37 (2H, d), 6.81 (2H, d), 4.70 (1H, t),  
                                 3.97 (2H, d), 3.45 (6H, s)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>    2940, 1555, 1485, 1070, 820, 645, 505

MS m/z                    262, 260(M<sup>+</sup>), 231, 199, 173, 75(100%)

### Step 2

#### Preparation of 5-Bromobenzo[b]furan

5-Bromobenzo[b]furan was prepared and purified in a similar manner to that described in Example 8 step 2 using the following reagents:

The product of step 1 (52.6 g, 202 mmol), polyphosphoric acid (85.0 g).

A colourless liquid was obtained.

Yield 20.2 g (51%), bp 80 °C at 0.01 mm Hg (lit.<sup>2</sup> 15°C).

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ        7.72 (1H, dd), 7.61 (1H, d), 7.38 (1H, dd),  
                                 6.71 (1H, d), 7.37 (1H, d)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>    1440, 1165, 1030, 800, 760, 670, 420

MS m/z                    198, 196(M<sup>+</sup>), 168, 155, 117, 89(100%)

### Step 3

#### Preparation of 5-Cyanobenzo[b]furan

A mixture of the product of step 2 (20.0 g, 102 mmol) and cuprous cyanide monohydrate (22.0 g, 204 mmol) in *N*-methylpyrrolidin-2-one (700 ml) was refluxed (24 h) with stirring. Reaction completion was indicated by glc analysis. The reaction mixture was allowed to cool and filtered through a pad of 'Hyflo Supercel'. It was then poured into water and ether added. The separated aqueous layer was extracted with ether (2 x 300 ml). The combined ethereal layers were washed with water and brine, dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The desired product was recrystallised from cyclohexane.

Colourless needles were obtained.

Yield 6.6 g (45%), mp 82-83 °C.

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.98 (1H, dd), 7.78 (1H, d), 7.61 (1H, d),  
7.60 (1H, dd), 6.89 (1H, dd)

5 IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  3150, 2200, 1755, 1600, 1550, 1185, 1010,  
885, 760, 610

MS  $m/z$  143( $\text{M}^+$ ), (100%), 88, 62, 50

#### **Step 4**

##### **Preparation of 5-Cyanobenzo[b]furan-2-boronic acid**

10 A solution of the product of step 3 (6.5 g, 45 mmol) in dry tetrahydrofuran (150 ml) was degassed and flushed with nitrogen. It was then cooled (-90°C) and n-butyllithium (2.5M in hexanes, 19.1 ml, 48 mmol) was added dropwise with stirring. Stirring was continued (0.5 h), and trimethyl borate (9.4 g, 90 mmol) was added at -100 °C. After stirring (20 min), hydrochloric acid (2M, 137 ml) was added and the  
15 mixture stirred for a further 15 min. After allowing to return to room temperature, the mixture was poured into water and ether added. The separated aqueous layer was washed with ether (2 x 200 ml). The combined organic layers were washed with water and brine, dried ( $\text{MgSO}_4$ ), and the solvent removed *in vacuo*.

An off-white solid was obtained.

20 Yield 7.2 g (86%).

MS  $m/z$  187( $\text{M}^+$ ), 160, 145, 117, 43(100%)

#### **Step 5**

##### **Preparation of 2-(4-Propylphenyl)-5-cyanobenzo[b]furan (Compound 42 in Table 1)**

25 Compound was prepared and purified in a similar manner to that described in Example 1 step 4 using the following reagents:

1-bromo-4-propylbenzene obtained as described in Example 2 step 4 (1.0 g, 5 mmol), the product of step 4 above (1.1 g, 6 mmol), sodium carbonate (1.3 g, 13 mmol), tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol).

30 Colourless crystals were obtained.

Yield 0.1 g (8%).

Purity (hplc) 98%.

Transitions (°C) K 98.0 Iso.

5	<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.93 (1H, dd), 7.79 (2H, d), 7.61 (1H, d), 7.55 (1H, dd), 7.31 (2H, d), 7.06 (1H, d), 2.65 (2H, t), 1.68 (2H, sxt), 0.96 (3H, t)
	IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2966, 2225, 1505, 1463, 1118, 818, 794, 738
	MS m/z	261(M <sup>+</sup> ), 232(100%), 202, 176, 58

### **Example 10**

#### **Preparation of 2-(4-Pentylphenyl)-5-cyanobenzo[b]furan Compound 27 in Table 1**

10 Compound 27 was prepared and purified in a similar manner to that described in Example 1 step 4 using the following reagents:

1-bromo-4-pentylbenzene obtained as described in Example 3 step 1 (1.1 g, 5 mmol), 5-cyanobenzo[b] (1.1 g, 6 mmol), sodium carbonate (1.3 g, 13 mmol), tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol).

15 Colourless crystals were obtained.

Yield 0.2 g (14%).

Purity (hplc) >99%.

Transitions (°C) K 99.7 (86.5 N) Iso.

20	<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.92 (1H, dd), 7.89 (2H, d), 7.61 (1H, d), 7.55 (1H, dd), 7.31 (2H, d), 7.05 (1H, d), 2.66 (2H, t), 1.65 (2H, qui), 1.35 (4H, m), 0.90 (3H, t)
	IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2933, 2865, 2224, 1504, 1461, 1185, 1115, 890, 800, 740
	MS m/z	289(M <sup>+</sup> ), (100%), 245, 232, 202, 219, 203

### **Example 11**

#### **Preparation of Compound 13 in Table 1**

##### **Step 1**

##### **Preparation of Methyl 3-chloromethyl-4-hydroxybenzoate**

30 A suspension of methyl 4-hydroxybenzoate (15.2 g, 100 mmol) in hydrochloric acid (conc, 130 ml) was cooled (5 °C) with stirring. Paraformaldehyde (3.3 g, 11

mmol) was then added, and the mixture was heated (50-55 °C). The mixture was left to stand overnight. The solid was then filtered off and washed with water. The crude product was dried overnight *in vacuo* (CaCl<sub>2</sub>), and recrystallised (CHCl<sub>3</sub>).

A white solid was obtained.

5 Yield 8.0 g (40%), mp 144-145 °C, (lit.<sup>3</sup> 147-149 °C).

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 8.03 (1H, d), 7.93 (1H, dd), 6.90 (1H, d),  
6.18 (1H, s), 4.68 (2H, s), 3.90 (3H, s)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3241, 2958, 1688, 1605, 1287, 1152, 844,  
754, 705

10 MS *m/z* 200(M<sup>+</sup>), 165(100%), 149, 133, 119

## **Step 2**

### **Preparation of 2-Hydroxy-5-(methoxycarbonyl)benzyltriphenylphosphonium chloride**

A mixture of the product of step 1 (7.9 g, 39 mmol) and triphenylphosphine  
15 (9.8 g, 37 mmol) in chloroform (100 ml) was refluxed (1 h). The mixture was allowed to cool and the solvent was removed *in vacuo*. The residue was washed with toluene, whence it solidified. After filtering off the toluene the product heated *in vacuo* (100 °C, 1h) and recrystallised (H<sub>2</sub>O).

Colourless crystals were obtained.

20 Yield 13.8 g (81%), mp 256-7 °C.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 11.37 (1H, s), 7.76 (3H, dt), 7.66 (1H,  
ddd), 7.59 (12H, m) 7.38 (1H, d), 7.38 (1H,  
d), 4.71 (2H, d), 3.76 (3H, s)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3400, 1693, 1606, 1435, 1291, 1113, 770,  
25 745, 690

MS *m/z* 426(M<sup>+</sup> - Cl<sup>-</sup>), 395, 349, 262(100%), 183

## **Step 3**

### **Preparation of Methyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate (Compound 11 in Table 1)**

30 *N,N'*-Dicyclohexylcarbodiimide (1.8 g, 9 mmol) in dry dichloromethane (20 ml) was added to a stirred mixture of 4-*N,N'*-(dimethylamino)pyridine (0.2 g, 1.6

mmol), the product of step 2 (3.2 g, 6.8 mmol) and 4-heptylbenzoic acid (1.8 g, 8 mmol), in dry dichloromethane (80 ml). Stirring was continued (24 h), and dry toluene (350 ml) was added. The dichloromethane was distilled off in a stream of nitrogen. Dry triethylamine (2.0 g, 20 mmol) was added and the mixture was heated (85 °C) with stirring under nitrogen (14 h). Tlc analysis indicated a complete reaction. After allowing to cool, the mixture was filtered and the solvent removed *in vacuo*. The residue was then flash chromatographed [silica gel / petroleum fraction (bp 40-60 °C), dichloromethane 6:4], and recrystallised (hexane). Colourless plate-like crystals were obtained.

Yield 1.3 g (55%).

Transitions (°C) K 101 SmF 104.5 SmA 114.9 Iso.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.30 (1H, dd), 7.98 (1H, dd), 7.79 (2H, d),  
7.55 (1H, d), 7.30 (2H, d), 7.07 (1H, d),  
3.92 (3H, s), 2.66 (2H, s), 1.62 (2H, qui),  
1.32 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2927, 2852, 1717, 1590, 1300, 1160, 1086,  
838, 766

MS *m/z* 350(M<sup>+</sup>), 319, 278, 265(100%), 206

### **Example 12**

#### **Preparation of 2-(4-Heptylphenyl)benzo[b]furan-5-carboxylic acid (Compound 43 in Table 1)**

Compound 43 was prepared and purified in a similar manner to that described in Example 1 step 5 using the following reagents:

Compound 24 obtained as described in Example 40 step 3 (4.2 g, 12 mmol), potassium hydroxide (1.4 g, 24 mmol).

Colourless needle-like crystals were obtained.

Yield 3.7 g (92%).

Transitions (°C) K 200.3 SmC 255.8 Iso

<sup>1</sup>H NMR DMSO-d<sub>6</sub>/δ 12.87 (1H, s), 8.25 (1H, s), 7.90 (1H, d),  
7.83 (2H, d), 7.68 (1H, d), 7.47 (1H, s),  
7.34 (2H, d), 2.61 (2H, t), 1.59 (2H, qui),  
1.26 (8H, m), 0.85 (3H, t)



**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3450, 2926, 2849, 2361, 1674, 1612, 1507,  
1168, 912, 836  
**MS**  $m/z$  336( $M^+$ ), 264, 251(100%), 206, 178

**Example 13**

5 **Preparation of 2-(4-heptylphenyl)benzo[b]furan-5-carboxamide (Compound 44 in Table 1)**

Compound 44 was prepared and purified in a similar manner to that described in Example 1 step 6 from the following reagents:

Compound 43 (Example 12) (1.0 g, 3 mmol), thionyl chloride (1.1 g, 9 mmol),  
10 ammonia, (d 0.880, 2.0 ml).  
A white solid was obtained.

Yield 0.6 g (60%), mp 242-243 °C.

**$^1\text{H}$  NMR** DMSO- $d_6/\delta$  8.10 (1H, d), 7.78 (2H, d), 7.77 (1H, d),  
7.54 (1H, d), 7.28 (2H, d), 6.81 (1H, s),  
15 5.85 (1H, s), 2.64 (2H, t), 1.63 (2H, qui),  
1.25 (8H, m), 0.87 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3419, 3192, 2922, 1646, 1608, 1391, 912,  
801

**MS**  $m/z$  335( $M^+$ ), 250(100%), 217, 206, 178

20 **Example 14**

**Preparation of Compound 54 in Table 1 (2-(4-Heptylphenyl)-5-cyanobenzo[b]furan)**

Compound 54 was prepared and purified in a similar manner to that described in Example 1 step 7 from the following reagents:

25 Compound 44 (Example 13) (0.6 g, 1.6 mmol), thionyl chloride (1.9 g, 16 mmol).  
Colourless crystals were obtained.

Yield 0.2 g (39%).

Purity (hplc) >99.9%.

Transitions (°C) K 86.5 N 87.5 Iso.

30  **$^1\text{H}$  NMR**  $\text{CD}_2\text{Cl}_2/\delta$  7.92 (1H, d), 7.79 (2H, d), 7.61 (1H, d),  
7.55 (1H, dd), 7.31 (2H, d), 7.05 (1H, s),

	2.66 (2H, t), 1.65 (2H, qui), 1.30 (8H, m), 0.89 (3H, t)
<b>IR</b> (KBr) $\nu_{\max}/\text{cm}^{-1}$	2920, 2840, 2229, 1616, 1504, 1119, 881, 741
5 <b>MS</b> $m/z$	317( $M^+$ ), 245, 232(100%), 203, 176

**Example 15****Preparation of Compound 45 in Table 1 (Methyl 2-(4-nonyloxyphenyl)benzo[b]furan-5-carboxylate)**

A suspension of 4-nonyloxybenzoic acid (3.2 g, 12 mmol) in thionyl chloride  
 10 (16.4 g, 138 mmol) was stirred overnight with exclusion of moisture. The solution was  
 then refluxed (1 h), and allowed to cool. The excess thionyl chloride was removed in  
 vacuo. Residual hydrogen chloride was removed by repeated addition of dry toluene,  
 followed by removal in vacuo. The acid chloride was then added to 2-hydroxy-5-  
 (methoxycarbonyl)benzyltriphenylphosphonium chloride obtained as described in  
 15 Example 11 step 2 (4.6 g, 10 mmol) and dry triethylamine (3.0 g, 30 mmol) in dry  
 toluene (45 ml), and the mixture was refluxed (18 h) with stirring under nitrogen. The  
 reaction was monitored by tlc analysis. The mixture was allowed to cool, the  
 precipitate of triethylammonium chloride was filtered off, and the solvent was  
 removed in vacuo. The product was purified by flash chromatography [silica gel /  
 20 petroleum fraction (bp 40-60 °C), dichloromethane 7:3], followed by recrystallization  
 (hexane).

A white solid was obtained.

Yield 0.9 g (22%).

Transitions (°C) K 151.5 SmA 152.0 Iso.

25 <b><sup>1</sup>H NMR</b> $\text{CD}_2\text{Cl}_2/\delta$	8.19 (1H, d), 7.87 (1H, dd), 7.72 (2H, d), 7.45 (1H, d), 6.90 (2H, d), 6.89 (1H, s), 3.93 (2H, t), 3.83 (3H s), 1.72 (2H, qui), 1.39 (2H, qui), 1.22 (10H, m), 0.81 (3H, t)
<b>IR</b> (KBr) $\nu_{\max}/\text{cm}^{-1}$	2920, 1722, 1612, 1506, 766
30 <b>MS</b> $m/z$	394( $M^+$ ), 268(100%), 237, 210, 182

**Example 16****Preparation of 2-(4-Nonyloxyphenyl)benzo[b]furan-5-carboxylic acid****(Compound 46 in Table 1)**

Compound 46 was prepared and purified in a similar manner to that described  
 5 in Example 1 step 5 from the following reagents:

Compound 45 obtained as described in Example 15 (0.8 g, 1.9 mmol), potassium  
 hydroxide (0.2 g, 4 mmol).

A white crystalline solid was obtained.

Yield 0.6 g (86%).

10 Transitions (°C) K 172 SmC 193.2 N 253.7 Iso.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>, DMSO-d<sub>6</sub>/δ 8.27 (1H, d), 7.97 (1H, dd), 7.81  
 (2H, d), 7.52 (1H, d), 7.00 (1H, d),  
 6.99 (2H, d), 4.02 (2H, t), 3.50 (1H,  
 s), 1.80 (2H, t), 1.48 (2H, m), 1.27  
 15 (10H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3450, 2920, 2857, 1679, 1615, 1504,  
 802, 769

MS m/z 380(M<sup>+</sup>), 363, 336, 254(100%), 225

**Example 17**

20 **Preparation of 2-(4-Nonyloxyphenyl)benzo[b]furan-5-carboxamide (Compound  
 47 in Table 1)**

Compound 47 was prepared and purified in a similar manner to that described  
 in Example 1 step 6 using the following reagents:

Compound 46 obtained as described in Example 16 (0.5 g, 1.4 mmol), thionyl chloride  
 25 (0.5 g, 4 mmol), ammonia, (d 0.880, 1.0 ml).

A white solid was obtained.

Yield 0.2 g (38%).

Transitions (°C) K 225 N 235 Iso.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 8.15 (1H, s), 7.83 (1H, d), 7.80 (2H, d),  
 30 7.62 (1H, s), 7.51 (1H, d), 6.99 (2H, d),  
 6.98 (1H, s), 6.53 (1H, s), 4.02 (2H, t), 1.81  
 (2H, qui), 1.42 (2H, m), 1.28 (10H, m), 0.89

(3H, t)  
**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3440, 3200, 2919, 2850, 1645, 1611, 1504,  
 835, 807, 770  
**MS**  $m/z$  379( $M^+$ ), 350, 336, 254(100%), 238

5 **Example 18**

**Preparation of 2-(4-Nonyloxyphenyl)-5-cyanobenzo[b]furan (Compound 16 in Table 1)**

Compound 16 was prepared and purified in a similar manner to that described in Example 1 step 7 using the following reagents.

10 Compound 47 from Example 17 (0.2 g, 0.5 mmol), thionyl chloride (0.6 g, 5 mmol).  
 A white solid was obtained.

Yield 0.04 g (22%).

Purity (hplc) 96.6%.

Transitions ( $^{\circ}\text{C}$ ) K 103.0 SmA 119.7 Iso.

15  **$^1\text{H}$  NMR**  $\text{CD}_2\text{Cl}_2/\delta$  7.90 (1H, dd), 7.80 (2H, d), 7.59 (1H, d),  
 7.53 (1H, dd), 7.00 (2H, d), 6.96 (1H, d),  
 4.02 (2H, t), 1.80 (2H, qui), 1.47 (2H, m),  
 1.34-1.26 (10H, m), 0.89 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2921, 2850, 2225, 1609, 1504, 1175, 1010,  
 20 875, 802

**MS**  $m/z$  361( $M^+$ ), 235(100%), 206, 190, 164

**Example 19**

**Preparation of Compound 48 in Table 1**

**Step 1**

25 **Preparation of Benzonitrile-4-boronic acid**

Benzonitrile-4-boronic acid was prepared and purified in a similar manner to that described in Example 9 step 4 using the following reagents:

4-Bromobenzonitrile (25.0 g, 37 mmol), n-butyllithium (2.5M in hexanes, 57.5 ml, 44 mmol), trimethyl borate (28.5 g, 274 mmol).

30 A white solid was obtained.

Yield 16.6 g (82%).

**MS**  $m/z$  147( $M^+$ ), 119, 103, 91, 43(100%)

**Step 2****Preparation of 2-Heptyl-5-bromobenzo[b]furan**

n-Butyllithium (2.5M in hexanes, 3.3 ml, 8 mmol) was added to dry diisopropylamine (0.9 g, 8 mmol) with stirring under nitrogen at -70 °C. The system  
5 was degassed and flushed with nitrogen and 5-bromobenzo[b]furan (Example 9 step 2) (1.5 g, 7.6 mmol) in dry tetrahydrofuran (30 ml) was added dropwise with stirring. After stirring for a further 20 min, n-heptyl iodide (2.6 g, 11 mmol), was added dropwise. The mixture was allowed to return to room temperature with stirring under nitrogen. It was then poured into water and ether added. The separated aqueous phase  
10 was washed with ether (2 x 50 ml) and the combined organic layers washed with water and brine, dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The residue was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by distillation.

A colourless liquid was obtained.

15 Yield 0.3 g (20%), bp 170 °C at 0.02 mm Hg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ      7.60 (1H, dd), 7.29 (1H, s), 7.28 (1H, s),  
6.36 (1H, s), 2.75 (2H, t), 1.73 (2H, qui),  
1.32 (8H, m), 0.88 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>      2933, 2861, 1600, 1165, 1051, 949, 898, 731,  
20 671, 582

MS m/z      296, 294(M<sup>+</sup>), 239, 211(100%), 158, 109

**Step 3****Preparation of 2-Heptyl-5-(4-cyanophenyl)benzo[b]furan (Compound 48 in Table 1)**

25 Compound 48 was prepared and purified in a similar manner to that described in Example 1 step 4 using the following reagents:

Benzonitrile-4-boronic acid from step 1 (0.2 g, 1.5 mmol), 2-heptyl-5-bromobenzo[b]furan from step 2 (0.4 g, 1.4 mmol), sodium carbonate (0.4 g, 3.5 mmol), tetrakis(triphenylphosphine)palladium(0) (0.05 g, 0.04 mmol).

30 A white solid was obtained.

Yield 0.03 g (7%).

Purity (hplc) 90.5%.

Transitions (°C) K 43.0 (30.9 N) Iso.

	<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.71 (5H, m), 7.47 (1H, d), 7.43 (1H, dd), 6.45 (1H, d), 2.77 (2H, t), 1.74 (2H, qui), 1.33 (8H, m), 0.87 (3H, t)
5	IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2934, 2861, 2229, 1608, 1468, 844, 808
	MS m/z	317(M <sup>+</sup> ), 274, 260, 232(100%), 190

### **Example 20**

#### **Preparation of Compound 28 in Table 1**

##### **Step 1**

##### **10 Preparation of 1-Bromo-4'-pentylbiphenyl**

4-Bromobiphenyl (35.0 g, 150 mmol), valeryl chloride (21.8 g, 181 mmol), aluminium chloride (22.0 g, 164 mmol), poly(methylhydrosiloxane) (24.0 g, 399 mmol) were reacted using a method analogous to that described in Example 1 step 1 except that dry 1,2-dichloroethane (600 ml) was used in place of dry dichloromethane.

15 The title product was recrystallised from ethanol.

A pale-brown solid was obtained.

Yield 21.1 g (46%), mp 94-96 °C (lit.[Jawdosiuk, 1977 #157] 95-96 °C).

	<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.56 (2H, d), 7.49 (2H, d), 7.48 (2H, d), 7.27 (2H, d), 2.64 (2H, t), 2.64 (2H, t), 1.65 (2H, qui), 1.36 (4H, m), 0.90 (3H, t)
20	IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2931, 2865, 1690, 1137, 1079, 803, 502
	MS m/z	304,302(M <sup>+</sup> ), 247(100%)165, 152, 139

##### **Step 2**

##### **Preparation of 4'-Pentylbiphenylboronic acid**

25 n-Butyllithium (2.5M in hexanes, 231 ml, 577 mmol) was added dropwise to a stirred solution of the product of step 1 in dry tetrahydrofuran (90 ml) at -70 °C under nitrogen. Stirring under nitrogen was continued (30 min) and trimethyl borate (6.9 g, 66 mmol) was added dropwise, maintaining the temperature below -10 °C. The system was allowed to return to room temperature with stirring under nitrogen.

30 Hydrochloric acid (5M, 14 ml) was then added with stirring. The mixture was poured into water and ether added. The separated aqueous layer was washed with ether (2 x

200 ml) and the combined organic layers were washed with water and brine, dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*.

A light-brown solid was obtained.

Yield 7.2 g (81%).

5 **MS** *m/z* 268(M<sup>+</sup>), 224, 183(100%), 167, 152

### **Step 3**

#### **Preparation of 2-Cyano-5-(4'-pentylbiphenyl)benzo[b]furan (Compound 28)**

2-Cyano-5-bromobenzo[b]furan obtained as described in Example 2 step 3 (0.6 g, 2.7 mmol) and sodium carbonate (0.7 g, 6.8 mmol) in 1,2-dimethoxyethane (5 ml),  
 10 were stirred under nitrogen. Tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol) was added, followed by the product of step 2 (1.1 g, 4.1 mmol) in 1,2-dimethoxyethane (10 ml), and the mixture heated (80 °C) with stirring under nitrogen (4 h). Completion of the reaction was indicated by glc and tlc analysis. After allowing to cool, the reaction mixture was poured into water and ether added. The separated  
 15 aqueous layer was washed with ether (2 x 100 ml), and the combined ethereal layers washed with brine and dried (MgSO<sub>4</sub>). After removal of the solvent *in vacuo* the residue was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C) (impurity); petroleum fraction (bp 40-60 °C), dichloromethane 7:3 (product)]. The desired product was then recrystallised (hexane).  
 20 Colourless needle-like crystals were obtained.

Yield 0.1 g (10%).

Purity (hplc) 99.9%.

Transitions (°C) K 134.0 B 147.3 N 255.6 Iso.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.94 (1H, dd), 7.82 (1H, dd), 7.71 (2H, d),  
 25 7.69 (2H, d), 7.66 (1H, ddd), 7.58 (2H, d),  
 7.57 (1H, d), 7.29 (2H, d), 2.66 (2H, t),  
 1.66 (2H, qui), 1.36 (4H, m), 0.92 (3H, t)

**IR** (KBr)  $\nu_{\max}$ /cm<sup>-1</sup> 2931, 2862, 2237, 1505, 1179, 949, 805

**MS** *m/z* 365(M<sup>+</sup>), (100%), 346, 308, 252, 58

**Example 21****Preparation of Compound 29 in Table 1****Step 1****Preparation of 2-(4'-Pentylbiphenyl)-5-cyanobenzo[b]furan**

5           Compound 29 was prepared and purified in a similar manner to that described in Example 1 step 4 using the following reagents:

1-Bromo-4'-pentylbiphenyl (Example 20 step 1) (1.5 g, 5 mmol), 5-cyanobenzo[b]furan-2-boronic acid (Example 9 step 40) (1.5 g, 8 mmol), sodium carbonate (1.3 g, 13 mmol), tetrakis(triphenylphosphine)palladium(0) (0.6 g, 0.6  
10 mmol)

The product was recrystallised from ethanol / dichloromethane 5:1.

A white crystalline solid was obtained.

Yield 0.3 g (16%).

Purity (hplc) >99%.

15           Transitions (°C) K 187.1 N 284.2 Iso.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ       7.96 (1H, d), 7.95 (2H, d), 7.73 (2H, d),  
7.63 (1H, d), 7.58 (2H, d), 7.56 (1H, dd),  
7.30 (2H, d), 7.13 (1H, d), 2.66 (2H, t),  
1.66 (2H, qui), 1.36 (4H, m), 0.91 (3H, t)  
20   IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>   2933, 2859, 2229, 1497, 1122, 913, 803, 746  
MS m/z                365(M<sup>+</sup>), 308, 277, 165, 43(100%)

**Example 22****Preparation of Compound 49 in Table 1****Step 1**

25   **Preparation of 5-Bromobenzo[b]furan-2-boronic acid**

Dry diisopropylamine (2.0 g, 20 mmol) was added to n-butyllithium (2.5M in hexanes, 8 ml, 20 mmol) at -10 °C, and the mixture was stirred under nitrogen (20 min). 5-Bromobenzo[b]furan obtained as described in Example 9 step 2 (3.5 g, 18 mmol) in dry ether (35 ml) was added and the mixture stirred (2 h) at -10 °C under  
30   nitrogen. Trimethyl borate (3.7 g, 36 mmol) was added maintaining low temperature, and the mixture was allowed to return to room temperature with stirring under nitrogen. Hydrochloric acid (5M, 15 ml) was added with stirring. The mixture was



then poured into water and ether added. The separated aqueous layer was washed with ether (2 x 50 ml) and the combined organic layers were washed with sodium hydroxide solution (10%, 30 ml). The separated aqueous layer was washed with light petroleum (40-60 °C fraction) and acidified to pH3 with hydrochloric acid (5M). It was then  
5 washed with ether (2 x 50 ml). The combined organic layers were washed with water and brine, dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*.

A pale-orange solid was obtained.

Yield 3.4 g (78%).

10 <sup>1</sup>H NMR DMSO-d<sub>6</sub>/δ 8.62 (2H, s), 7.92 (1H, d), 7.56 (1H, d),  
7.46 (1H, dd), 7.42 (1H, s)  
MS *m/z* 196(M<sup>+</sup>-B(OH)<sub>2</sub>), 165, 151, 117, 89(100%),

### Step 2

#### Preparation of 1-Iodo-4-pentylbenzene

1-Iodo-4-pentylbenzene was prepared and purified in a similar manner to that  
15 described in Example 1 step 1 using the following reagents:  
Iodobenzene (20.4 g, 100 mmol), valeryl chloride (14.5 g, 120 mmol), aluminium chloride (14.7 g, 110 mmol), poly(methylhydrosiloxane) (16.0 g 267 mmol).  
A pale-yellow liquid was obtained.

Yield 14.4 g (53%), bp 105 °C at 0.01 mm Hg.

20 <sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.58 (2H, d), 6.93 (2H, d), 2.54 (2H, t),  
1.58 (2H, m), 1.31 (4H, m), 0.89 (3H, t)  
IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2962, 2862, 1486, 1118, 1065, 825, 795  
MS *m/z* 274(M<sup>+</sup>), 217(100%), 203, 175, 89

### Step 3

#### Preparation of 2-(4-pentylphenyl)-5-bromobenzo[b]furan (Compound 49 in Table 1)

25

Compound 49 was prepared and purified in a similar manner to that described in Example 1 step 4 using the following reagents:

1-Iodo-4-pentylbenzene from step 2(3 g, 11 mmol), 5-bromobenzo[b]furan-2-boronic  
30 acid from step 1(1.3 g, 5 mmol), sodium carbonate (1.4 g, 13.5 mmol),  
tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol)

The product was recrystallised from hexane.

A white crystalline product was obtained.

Yield 0.3 g (16%), mp 147-150 °C.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.765 (2H, d), 7.71 (1H, dd), 7.41 (1H, d),  
7.36 (1H, dd), 7.28 (2H, d), 6.96 (1H, d),  
2.66 (2H, t), 1.65 (2H, qui), 1.34 (4H, m),  
0.90 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2932, 2860, 1610, 1583, 1162, 873, 795, 670,  
508

MS *m/z* 344, 342(M<sup>+</sup>), 287(100%), 274, 206, 152

#### 10 **Example 23**

##### **Preparation of Compound 50 in Table 1 (2-(4-pentylphenyl)-5-(4'-cyanophenyl)benzo[b]furan)**

Compound 50 was prepared in a similar manner to that described in Example 1 step 4 using the following reagents:d.

15 Compound 49 (Example 22) (0.3 g, 0.9 mmol), benzonitrile-4-boronic acid (Example 19 step 1)(0.2 g, 1.0 mmol), sodium carbonate (0.2 g, 2 mmol),  
tetrakis(triphenylphosphine)palladium(0) (0.03 g, 0.03 mmol)

The product was purified by flash chromatography [silica gel / hexane, propionitrile 40:1], followed by recrystallisation (ethanol).

20 A white solid was obtained.

Yield 0.04 g (12%).

Purity (hplc) 98%.

Transitions (°C) K 133.8 N 230.5 Iso.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.74 (1H, d), 7.73 (2H, d), 7.68 (4H, s),  
7.53 (1H, d), 7.45 (1H, dd), 7.23 (2H, d),  
6.99 (1H, d), 2.58 (2H, t), 1.58 (2H, qui),  
1.27 (4H, m), 0.83 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2927, 2854, 2226, 1607, 1463, 1153, 1125,  
889, 841, 813

30 MS *m/z* 365(M<sup>+</sup>), 308(100%), 264, 176, 154

**Example 24****Preparation of Compound 35 in Table 1****Step 1****Preparation of 5-(4-Pentylphenyl)benzo[b]furan**

- 5            5-(4-Pentylphenyl)benzo[b]furan was prepared in a similar manner to that described in Example 1 step 4 from the following reagents:  
 5-Bromobenzo[b]furan (Example 9 step 20 (2.5 g, 13 mmol), 4-pentylbenzeneboronic acid (Example 3 step 2) (2.9 g, 15 mmol), sodium carbonate (3.5 g, 33 mmol), tetrakis(triphenylphosphine)palladium(0) (0.5 g, 0.5 mmol)  
 10    The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (hexane).  
 Colourless plate-like crystals were obtained.

Yield 1.2 g (35%), mp 62-64 °C.

- <sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ      7.54 (2H, d), 7.53 (1H, d), 7.52 (1H, dd),  
 15                              7.27 (2H, d), 6.84 (1H, dd), 2.65 (2H, t),  
                                  1.66 (2H, qui), 1.36 (4H, m), 0.91 (3H, t)  
 IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup>      2958, 2931, 2858, 1516, 1131, 885, 845, 806, 771, 743  
 MS m/z                      264(M<sup>+</sup>), 207(100%), 178, 165, 152

**Step 2**

- 20    **Preparation of 5-(4-Pentylphenyl)benzo[b]furan-2-boronic acid 5-(4-**

Pentylphenyl)benzo[b]furan-2-boronic acid was prepared and purified in a similar manner to that described in Example 20 step 2 from the following reagents:  
 5-(4-Pentylphenyl)benzo[b]furan from step 1 (1.2 g, 5 mmol), n-butyllithium (2.5M in hexanes, 2 ml, 5 mmol), trimethyl borate (0.9 g, 9 mmol).

- 25    A pale-pink solid was obtained.

Yield 1.2 g (84%).

MS m/z                      264(M<sup>+</sup>-B(OH)<sub>2</sub>), 207(100%), 177, 151, 127

**Step 3**

**Preparation of 2-(4-Cyanophenyl)-5-(4'-pentylphenyl)benzo[b]furan (Compound 35 in Table 1)**

- 30            Compound 35 was prepared and purified in a similar manner to that described in Example 20 step 3 from the following reagents:

Benzonitril-4-boronic acid (example 19 step 1) (0.7 g, 4 mmol), the product of step 2 above (1.1 g, 4 mmol), sodium carbonate (1.1 g, 10 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol).

The product was recrystallised from carbon tetrachloride.

5 Colourless, rhombic crystals were obtained.

Yield 0.4 g (30%).

Purity (hplc) 99.9%.

Transitions (°C) K 139.0 N 252.6 Iso

10 <sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.99 (2H, d), 7.83 (1H, dd), 7.76 (2H, d),  
7.62-7.57 (2H, m), 7.55 (2H, d), 7.29 (2H, d), 7.27 (2H, d), 2.66 (2H, t), 1.66 (2H, qui), 1.38-1.34 (4H, m), 0.92 (3H, t)  
IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2968, 2854, 2224, 1607, 1155, 842, 802  
MS *m/z* 365(M<sup>+</sup>), 308(100%), 277, 252, 154

## 15 **Example 25**

### **Preparation of Compound 51 in Table 1**

#### **Step 1**

#### **Preparation of 2-(4-Pentylphenoxy)acetaldehyde dimethyl acetal**

20 2-(4-Pentylphenoxy)acetaldehyde dimethyl acetal  
was prepared and purified in a similar manner to that described in Example 8 step 1 using the following reagents;

4-Pentylphenol (9.9 g, 60 mmol), bromoacetaldehyde dimethyl acetal (12.4 g, 73 mmol), potassium carbonate (20.8 g, 151 mmol), potassium iodide (0.6 g, 4 mmol). A pale-yellow liquid was obtained.

25 Yield 4.8 g (32%), bp 125 °C at 0.01 mm Hg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.08 (2H, d), 6.84 (2H, d), 4.72 (1H, t),  
3.99 (2H, t), 3.46 (6H, s), 2.53 (2H, t),  
1.57 (2H, qui), 1.31 (4H, m), 0.88 (3H, t)  
IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2936, 1616, 1514, 1247, 1139, 1081, 976,  
30 827, 757  
MS *m/z* 252(M<sup>+</sup>), 221, 149, 107, 75(100%)

**Step 2****Preparation of 5-Pentylbenzo[b]furan**

5-Pentylbenzo[b]furan was prepared and purified in a similar manner to that described in Example 8 step 2 from the following reagents;

5 The product of step 1 above (4.8 g, 19 mmol), polyphosphoric acid (4.6 g).

A colourless liquid was obtained.

Yield 2.2 g (62%), bp 125 °C at 0.1 mm Hg.

10	<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.61 (1H, d), 7.41 (1H, s), 7.40 (1H, d), 7.13 (1H, dd), 6.74 (1H, dd), 2.70 (2H, t), 1.65 (2H, qui), 1.35 (4H, m), 0.91 (3H, t)
	IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2934, 2861, 1468, 1198, 1033, 881, 812, 764, 734
	MS m/z	188(M <sup>+</sup> ), 145, 131(100%), 115, 91

**Step 3****Preparation of 5-Pentylbenzo[b]furan-2-boronic acid**

The product of step 2 (2.2 g, 12 mmol), n-butyllithium (2.5M in hexanes, 5.2 ml, 13 mmol), trimethyl borate (2.59 g, 24 mmol) were reacted using a method analogous to that described in Example 20 step 2 to yield the title compound.

A pale-orange solid was obtained.

20 Yield 2.7 g (97%).

MS m/z 232(M<sup>+</sup>), 187, 174, 146, 130(100%),

**Step 4****Preparation of 4-Cyano-4'-iodobiphenyl**

4-Cyano-4'-iodobiphenyl was prepared and purified in a similar manner to that described in Example 1 step 4 from the following reagents:

25 p-Diiodobenzene (14.7 g, 44 mmol), benzonitrile-4-boronic acid (Example 19 step 1)(5.0 g, 34 mmol), sodium carbonate (21.6 g, 204 mmol), tetrakis(triphenylphosphine)palladium(0) (3.0 g, 3 mmol).

The product was recrystallised from ethanol.

30 A white crystalline product was obtained.

Yield 1.0 g (10%), mp 174-176 °C (lit.[Pummerer, 1931 #158] 166 °C).

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.83 (2H, d), 7.74 (2H, d), 7.68 (2H, d),

7.37 (2H, d)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2227, 1604, 1477, 997, 853, 813, 561MS  $m/z$  305( $M^+$ ), (100%), 178, 151, 127, 75**Step 5**5 **Preparation of 2-(4'-Cyanobiphenyl)-5-pentylbenzo[b]furan (Compound 51 in Table 1)**

Compound 51 was prepared and purified from the product of step 4 above (1.0 g, 3 mmol), the product of step 3 above (0.8 g, 4 mmol), sodium carbonate (0.9 g, 8 mmol) and tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol) in method

10 analogous to that described in Example 20 step 3.

The product was recrystallised from ethanol.

Colourless, plate-like crystals were obtained.

Yield 36 mg (2%).

Purity (hplc) 99.5%.

15 Transitions ( $^{\circ}\text{C}$ ) K 150.8 B 167.0 N 280.3 Iso.

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.97 (2H, d), 7.79-7.75 (4H, m), 7.72 (2H, d), 7.44 (1H, d), 7.42 (1H, d), 7.15 (1H, dd), 7.09 (1H, d), 2.71 (2H, t), 1.67 (2H, qui), 1.38-1.33 (4H, m), 0.91 (3H, t)

20 IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2927, 2858, 2229, 1603, 1493, 1465, 1189, 825, 802

MS  $m/z$  365( $M^+$ ), 322, 308(100%), 264, 154

**Example 26****Preparation of Compound 52 in Table 1**25 **Step 1****Preparation of 2-Pentyl-5-bromobenzo[b]furan**

2-Pentyl-5-bromobenzo[b]furan was prepared and purified in a similar manner to that described in Example 19 step 2 using the following reagents;

5-Bromobenzo[b]furan (Example 9 step 2) (12.0 g, 61 mmol), dry diisopropylamine (6.8 g, 67 mmol), n-butyllithium (2.5M in hexanes, 26.8 ml, 67 mmol), n-pentyl iodide

30 (24.2 g, 122 mmol).

A colourless liquid was obtained.

Yield 2.6 g (16%), bp 198 °C at 0.6 mm Hg.

5	<b><sup>1</sup>H NMR</b> CD <sub>2</sub> Cl <sub>2</sub> /δ	7.61 (1H, dd), 7.30 (1H, d), 7.28 (1H, d), 6.36 (1H, s), 2.76 (2H, dt), 1.74 (2H, d), 1.37 (4H, m), 0.91 (3H, t)
	<b>IR</b> (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2935, 2868, 1599, 1450, 1117, 1050, 948, 867, 671, 579
	<b>MS</b> m/z	268, 266(M <sup>+</sup> ), 251, 223, 208(100%), 116

## **Step 2**

### **Preparation of 2-Pentylbenzo[b]furan-5-boronic acid**

10 The title compound was prepared and purified from the product of step 1 (2.5 g, 9 mmol), magnesium (0.3 g, 11 mmol) and trimethyl borate (2.09 g, 19 mmol) in a similar manner to that described in Example 1 step 2.  
A pale-yellow solid was obtained.

Yield 1.7 g (78%).

15	<b>MS</b> m/z	642(3M <sup>+</sup> -3H <sub>2</sub> O), 585, 255, 188, 131(100%)
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## **Step 3**

### **Preparation of 2-Pentyl-5-(4-(4'-cyano)biphenyl)benzo[b]furan (Compound 52 in Table 1)**

20 Compound 52 was prepared and purified in a similar manner to that described in Example 1 step 4 from the product of step 3 above (1.7 g, 7 mmol), 4-cyano-4'-iodobiphenyl (Example 25 step 2) (1.7 g, 6 mmol), sodium carbonate (1.5 g, 14 mmol), and tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol). The reaction was carried out with exclusion of light.

A white crystalline solid was obtained.

25 Yield 0.1 g (5%).  
Purity (hplc) 97.6%.  
Transitions (°C) K 94.8 N 236.7 Iso.

30	<b><sup>1</sup>H NMR</b> CD <sub>2</sub> Cl <sub>2</sub> /δ	7.77-7.68 (9H, m), 7.48 (1H, dd), 7.47 (1H, d), 6.45 (1H, s), 2.78 (2H, t), 1.76 (2H, t), 1.40-1.34 (4H, m), 0.90 (3H, t)
	<b>IR</b> (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2935, 2860, 2228, 1604, 1466, 1120, 948,

829, 802

MS *m/z* 365(M<sup>+</sup>), 350, 322, 308(100%), 278**Example 27****Preparation of Compound 53 in Table 1**5 **Step 1****Preparation of Benzo[b]furan-5-boronic acid**

Benzo[b]furan-5-boronic acid was prepared and purified from 5-bromobenzo[b]furan (Example 9 step 2) (2.0 g, 10 mmol), magnesium (0.3 g, 12 mmol) and trimethyl borate (2.1 g, 20 mmol) in a similar manner to that described in

10 Example 1 step 2.

A light-brown solid was obtained.

Yield 0.7 g (43%)

MS *m/z* 432(3M<sup>+</sup>-3H<sub>2</sub>O), 144(100%), 117, 89, 63**Step 2**15 **Preparation of 4-(4'-Pentylcyclohexyl)phenyl trifluoromethanesulphonate**

Trifluoromethanesulphonic anhydride (6.5 g, 23 mmol) was added dropwise to a stirred, cooled (0 °C) solution of 4-(*trans*-n-pentylcyclohexyl)phenol (5.0 g, 20 mmol) in dry pyridine (80 ml) under dry nitrogen. The mixture was stirred at room temperature overnight. It was then poured into water and ether added. The separated

20 aqueous layer was washed with ether (2 x 100 ml). The combined organic layers were washed with water, hydrochloric acid (10%) (twice), and brine, dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C), dichloromethane 7:3]

A pale yellow oil was obtained.

25 Yield 5.2 g (69%).

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.21 (2H, d), 7.10 (2H, d), 2.44 (1H, tt),  
1.82-1.81 (2H, m), 1.78-1.77 (2H, m), 1.38-  
1.36 (1H, m), 1.34-1.31 (1H, m), 1.26-1.12  
(9H, m), 1.02-0.99 (1H, m), 0.96-0.93 (1H,  
30 m), 0.81 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 2858, 1503, 1427, 1143, 1018, 837,  
740, 607



MS  $m/z$  378( $M^+$ ), 307, 252, 175, 69(100%)

### **Step 3**

#### **Preparation of 5-(4'-Pentylcyclohexyl-4-phenyl)benzo[b]furan**

5-(4'-Pentylcyclohexyl-4-phenyl)benzo[b]furan, a compound of formula  
5 (IXA), was prepared and purified in a similar manner to that described in Example 1  
step 4 from the following reagents:  
the product of step 2 above (3.4 g, 9 mmol), the product of step 1 above (1.6 g, 10  
mmol), sodium carbonate (2.4 g, 23 mmol), tetrakis(triphenylphosphine)palladium(0)  
(0.3 g, 0.3 mmol)  
10 Volatiles were removed by heating (95 °C) *in vacuo* (12 h).  
A white solid was obtained.

Yield 1.9 g (61%).

Transitions (°C) K 116.3 N 153.7 Iso.

15  $^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.80-7.79 (1H, m), 7.67 (1H, d), 7.56-7.51  
(4H, m), 7.30 (2H, d), 6.84 (1H, dd), 2.53  
(1H, tt), 1.94-1.88 (4H, m), 1.48 (2H, ddd), 1.35-1.22 (9H,  
m), 1.08 (2H, ddd), 0.91 (3H, t)

IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  3124, 2924, 2853, 1463, 1131, 1027, 883,  
742, 697

20 MS  $m/z$  346( $M^+$ ), 331, 303, 275, 233(100%)

### **Step 4**

#### **Preparation of 5-(4'-Pentylcyclohexyl-4-phenyl)benzo[b]furan-2-carboxylic acid (Compound 53)**

Compound 53 was prepared and purified from the product of step 3 (1.9 g, 5.5  
25 mmol) and n-butyllithium (2.5M in hexanes, 2.4 ml, 6.1 mmol) in a similar manner to  
that described for in Example 8 step 3.

A white solid was obtained.

Yield 2.0 g (79%).

Transitions (°C) K 183 N 299 Iso.

30  $^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.79 (1H, dd), 7.59 (1H, dd), 7.54 (1H, d),  
7.47 (2H, d), 7.45 (1H, d), 7.23 (2H, d),  
2.45-2.42 (1H, m), 1.85-1.80 (4H, m), 1.43

(2H, ddd), 1.27-1.13 (9H, m), 1.00 (2H, ddd), 0.82 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2929, 2853, 1691, 1566, 1173, 813

**MS**  $m/z$  390( $M^+$ ), (100%), 346, 333, 264, 189

### **Example 28**

#### **5 Preparation of Compound 54 in Table 1(5-(4'-Pentylcyclohexyl-4-phenyl)benzo[b]furan2-carboxamide)**

Compound 54 was prepared and purified in a similar manner to that described in Example 1 step 6 using the following reagents:

Compound 53 (Example 27) (2.0 g, 4.3 mmol), thionyl chloride (1.5 g, 13 mmol), ammonia, (d 0.880, 2.9 ml).

Fibrous white needle-like crystals were obtained.

Yield 1.1 g (66%).

Transitions ( $^{\circ}\text{C}$ ) K 275 N 296 Iso.

**$^1\text{H}$  NMR**  $\text{CD}_2\text{Cl}_2/\delta$ , DMSO- $d^6/\delta$  7.83 (1H, d), 7.63 (1H, dd), 7.56 (1H, d), 7.53 (2H, d), 7.46 1H, d), 6.92 (1H, s), 6.54 (1H, s), 2.42-2.35 (1H, m), 1.91-1.85 (4H, m), 1.47 (2H, ddd), 1.32-1.20 (9H, m), 1.05 (2H, ddd), 0.88 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3393, 3170, 2928, 2852, 1675, 1615, 1168, 817

**MS**  $m/z$  389( $M^+$ ), 316, 301, 250, 58(100%)

### **Example 29**

#### **25 Preparation of 2-Cyano-5-(4'-trans-pentylcyclohexyl-4-phenyl)benzo[b]furan (Compound 54 in Table 1)**

Compound 54 was prepared and purified in a similar manner to that described in Example 1 step 7 from compound 54 (Example 28) (1.0 g, 2.6 mmol) and thionyl chloride (3.2 g, 26 mmol).

The product was recrystallised from ethanol.

Yield 0.5 g (52%).

Purity (hplc) >99%.

Transitions ( $^{\circ}\text{C}$ ) K 113.0 N 240.7 Iso.

5	<b><sup>1</sup>H NMR</b> CD <sub>2</sub> Cl <sub>2</sub> /δ	7.86 (1H, dd), 7.75 (1H, dd), 7.61 (1H, dt), 7.55 (1H, d), 7.54 (2H, d), 7.32 (2H, d), 2.53 (1H, tt), 1.93-1.87 (4H, m), 1.56-1.44 (4H, m), 1.35-1.19 (7H, m), 1.08 (2H, m), 0.90 (3H, t)
	<b>IR</b> (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2925, 2854, 2234, 1558, 1515, 1462, 1178, 1128, 950, 887
	<b>MS</b> <i>m/z</i>	371(M <sup>+</sup> )(100%), 300, 245, 232, 189

**Example 30****10 Preparation of Compound 56 in Table 1****Step 1**

**Preparation of Ethyl 5-methoxybenzo[b]furan-2-carboxylate** Ethyl 5-methoxybenzo[b]furan-2-carboxylate was prepared and purified from 5-methoxysalicylaldehyde (20.0 g, 131 mmol), diethyl bromomalonate (26.3 g, 150 mmol), potassium carbonate (32.5 g, 236 mmol), potassium iodide (0.9 g, 6 mmol), in a similar manner to that described in Example 1 step 3.

Colourless cubic crystals were obtained.

Yield 14.5 g (50%), mp 58-59.5 °C, bp 150 °C at 0.02 mm Hg.

20	<b><sup>1</sup>H NMR</b> CD <sub>2</sub> Cl <sub>2</sub> /δ	7.47 (1H, ddd), 7.45 (1H, d), 7.09 (1H, d), 7.06 (1H, dd), 4.39 (2H, q), 3.83 (3H, s), 1.40 (3H, t)
	<b>IR</b> (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2988, 1721, 1560, 1195, 940, 846, 822
	<b>MS</b> <i>m/z</i>	220(M <sup>+</sup> ), (100%), 205, 192, 175, 119

**Step 2****25 Preparation of 5-Methoxybenzo[b]furan-2-carboxylic acid**

The title compound was prepared and purified from the product of step 1 (14.5 g, 66 mmol) and potassium hydroxide (7.3 g, 130 mmol) in a similar manner to that described in Example 1 step 5.

Colourless crystals were obtained.

30 Yield 6.1 g (48%).

Transitions (°C) K 208 N 221 Iso.

<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> , DMSO-d <sub>6</sub> /δ	11.5 (1H, s), 7.41 (1H, d), 7.38 (1H, d), 7.06 (1H, d), 7.00 (1H, dd), 3.78 (3H, s)
IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2953, 1689, 1566, 1160, 943, 898, 850, 797
MS m/z	192(M <sup>+</sup> )(100%), 177, 162, 149, 107

**Step 3****Preparation of 5-Methoxybenzo[b]furan-2-carboxamide**

The title compound was prepared and purified from the product of step 2 (6.0 g, 31 mmol), thionyl chloride (11.0 g, 93 mmol) and ammonia (d 0.880, 11.0 ml) in a similar manner to that described in Example 1 step 6.

Colourless plate-like crystals were obtained.

Yield 4.6 g (78%).

<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.42 (2H, d), 7.40 (1H, s), 7.11, (1H, d), 7.04 (1H, dd), 6.53 (1H, s, br), 5.94 (1H, s, br), 3.84 (3H, s)
IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	3451, 3138, 1692, 1608, 1476, 1156, 854, 833
MS m/z	191(M <sup>+</sup> )(100%), 175, 159, 148, 133

**Step 4****Preparation of 2-Cyano-5-methoxybenzo[b]furan**

The product of step 3 (4.8 g, 25 mmol) and thionyl chloride (14.3 g, 120 mmol) were converted to the title compound in a similar manner to that described in Example 1 step 7.

The product was recrystallised from methanol.

White needle-like crystals were obtained.

Yield 1.5 g (36%), mp 79.5-80 °C.

<sup>1</sup> H NMR CD <sub>2</sub> Cl <sub>2</sub> /δ	7.46 (1H, ddd), 7.44 (1H, dd), 7.12 (1H, dd), 7.09 (1H, d), 3.84 (3H, s)
IR (KBr) ν <sub>max</sub> /cm <sup>-1</sup>	2949, 2842, 2231, 1596, 1475, 1211, 1185, 949, 877, 750
MS m/z	173(M <sup>+</sup> ), (100%), 158, 130, 102, 75

**Step 5****Preparation of 2-Cyano-5-hydroxybenzo[b]furan**

A mixture of the product of step 4 (0.7 g, 4 mmol) and pyridinium chloride (4.6 g, 40 mmol) was refluxed (3 min). The reaction mixture was then poured into ice /  
5 water. The product was extracted into ether (2 x 200 ml), and the combined organic extracts were washed with water and brine and dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The product was recrystallised from ethanol. Colourless crystals were obtained.

Yield 0.5 g (80%).

**Step 6****Preparation of 2-Cyanobenzo[b]furan-5-trans-(oxycarbonyl-4-pentylcyclohexane) (Compound 56 in Table 1)**

The product of step 5 (0.5 g, 3 mmol) and *trans*-4-pentylcyclohexylcarboxylic acid (0.6 g, 3 mmol) were dissolved in dry dichloromethane (30 ml) and (4-*N,N*-  
15 dimethylamino)pyridine (0.1 g, 1 mmol) was added, and the mixture stirred. *N,N'*-Dicyclohexylcarbodiimide (0.6 g, 3 mmol) was then added, and stirring was continued (24 h). The reaction was monitored by tlc analysis. The precipitate of *N,N'*-dicyclohexylurea was filtered off, and the solvent removed *in vacuo*. The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C),  
20 dichloromethane 7:3], followed by recrystallization (ethanol). A white crystalline solid was obtained.

**Example 31****Preparation of Compound 100 in Table 2****Step 1****Preparation of 4-Bromo(2,2-dimethoxy)ethyl sulphanylbenzene**

Sodium (13.8 g, 600 mmol) was added to superdry ethanol (400 ml) with stirring under nitrogen. 4-Bromothiophenol (compound **102**) (103.3 g, 546 mmol) was added and stirring was continued (5 min). Bromoacetaldehyde dimethyl acetal (120.0 g, 709 mmol) was then added and the mixture refluxed overnight with stirring under  
30 nitrogen. The mixture was then washed with dichloromethane (3 x 100 ml). The combined washings were washed with water and brine, dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The residue was purified by distillation. A colourless oil was obtained.

Yield 104.3 g (69%) bp 132 °C at 2 mm Hg.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.39 (2H, d), 7.24 (2H, d), 4.5 (1H, t),  
3.36 (6H, s), 3.08 (2H, d)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2930, 2830, 1470, 1120, 1090, 800, 480

5 MS *m/z* 278,276(M<sup>+</sup>), 247, 215, 201, 189, 75(100%)

## **Step 2**

### **Preparation of 5-Bromobenzo[b]thiophene**

The product of step 1, (104.3 g, 376 mmol) and polyphosphoric acid (156.2 g) were converted to 5-bromobenzo[b]thiophene in Example 8 step 2. A white  
10 crystalline solid was obtained.

Yield 12.0 g (15%), mp 46-47 °C (lit<sup>4</sup> 47-48 °C).

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.98 (1H, d), 7.77 (1H, d), 7.52 (1H, d),  
7.44 (1H, dd), 7.30 (1H, dd)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3080, 1576, 1399, 898, 807, 472

15 MS *m/z* 214,212(M<sup>+</sup>), 133(100%), 106, 89, 81

## **Step 3**

### **Preparation of 5-(4-Heptylphenyl)benzo[b]thiophene**

The product of step 2 (4.6 g, 22 mmol), 4-heptylbenzeneboronic acid (Example 1 step 2) (5.7 g, 26 mmol), sodium carbonate (5.8 g, 55 mmol) and  
20 tetrakis(triphenylphosphine)palladium(0) (0.8 g, 0.7mmol) were treated as described in Example 1 step 4 to give the title compound. A colourless was obtained, which solidified on cooling.

Yield 4.8 g (71%), bp 225 °C at 0.01 mm Hg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.95 (1H, d), 7.85 (1H, d), 7.51 (1H, dd),  
25 7.50 (2H, d), 7.42 (1H, d), 7.31 (1H, dd),  
7.20 (2H, d), 2.57 (2H, t), 1.57 (2H, qui),  
1.28-1.20 (8H, m), 0.81 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 2857, 1496, 1089, 899, 805, 757

MS *m/z* 308(M<sup>+</sup>), 252, 223(100%), 167, 58

**Step 4****Preparation of 5-(4-Heptylphenyl)benzo[b]thiophene-2-carboxylic acid****(Compound 100 in Table 2)**

Compound 100 was prepared and purified in a similar manner to that described  
 5 in Example 8 step 3 using the following reagents:

the product of step 3 above (2.5 g, 8 mmol) and n-butyllithium (2.5M in hexanes, 3.4 ml, 9 mmol).

A white solid was obtained.

Yield 1.1 g (39%), mp 164-170 °C.

10 **<sup>1</sup>H NMR** CD<sub>2</sub>Cl<sub>2</sub>, DMSO-d<sub>6</sub>/δ 8.05 (1H, d), 8.02 (1H, s), 7.90 (1H, d), 7.68 (1H, dd), 7.55 (2H, d), 7.26 (2H, d), 2.63 (2H, t), 1.62 (2H, qui), 1.32-1.23 (8H, m), 0.86 (3H, t) (acidic proton signal was not shown)

15 **IR** (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3010, 2931, 2855, 1690, 1547, 1514, 1165, 803, 757, 700

**MS** m/z 352(M<sup>+</sup>), 281, 267(100%), 221, 208

**Example 32****Preparation of 5-(4-Heptylphenyl)benzo[b]thiophene-2-carboxamide (Compound****101 in Table 2)**

Compound 101 was prepared and purified in a similar manner to that described  
 20 in Example 1 step 6 from compound 57 (Example 31)(1.1 g, 3 mmol), thionyl chloride (1.1 g, 9 mmol) and ammonia (d 0.880, 1.1 ml).

A white crystalline solid was obtained.

25 Yield 1.8 g (92%), mp 204-205 °C.

**<sup>1</sup>H NMR** CD<sub>2</sub>Cl<sub>2</sub>/δ 8.06 (1H, d), 7.93 (1H, d), 7.81 (1H, s), 7.70 (1H, dd), 7.58 (2H, d), 7.30 (2H, d), 2.66 (2H, t), 1.65 (2H, qui), 1.36-1.26 (8H, m), 0.89 (3H, t) (H-bonded proton signals  
 30 were not shown)

**IR** (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3399, 3187, 2927, 2855, 1643, 1609, 1512,

1172, 800

MS *m/z* 351(M<sup>+</sup>), 279, 266(100%), 248, 221**Example 33****Preparation of 2-Cyano-5-(4-heptylphenyl)benzo[b]thiophene (Compound 102 in****Table 2)**

Compound 102 was prepared and purified in a similar manner to that described in Example 1 step 7 from Compound 61 (Example 31) (1.0 g, 3 mmol), thionyl chloride (3.3 g, 28 mmol).

A white crystalline solid was obtained.

Yield 0.4 g (43%), mp 93.2 °C.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.1 (1H, d), 7.97 (1H, d), 7.94 (1H, d),  
7.80 (1H, dd), 7.57 (2H, d), 7.31 (2H, d),  
2.66 (2H, t), 1.65 (2H, qui), 1.35-1.30 (8H, m), 0.89 (3H, t)

**Example 34****Preparation of 4-Heptylphenyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate (Compound 5 in Table 1)****Step 1****Preparation of 4-Heptylphenol**

Hydrogen peroxide (100 vol, 387 ml, 3.39 mol) was added slowly to a stirred solution of 4-heptyl benzeneboronic acid (15.8 g, 72.0 mmol) in dry diethyl ether (100 ml) and the mixture was refluxed (2 h). After allowing to cool, the mixture was washed with ether (3 x 150 ml). The combined ethereal layers were washed with saturated sodium sulphite solution and shaken with aqueous sodium hydroxide (2M). The white precipitate was filtered off and washed with petroleum fraction (bp 40-60 °C), and then adjusted to pH 3 with hydrochloric acid (conc.). The product was extracted by washing with ether (3 x 150 ml). The combined organic layers were washed with brine and dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The residue was purified by distillation.

A colourless liquid was obtained.

Yield 4.4 g (32 %) bp 115 °C at 0.03 mmHg (lit.<sup>1</sup> 65°C).

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.02 (2H, d), 6.76 (2H, d), 5.10 (1H, s),



2.53 (2H, d) 1.56 (2H, m), 1.31 (8H, m),  
0.87 (3H, t)

IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  3340, 2925, 1615, 1515, 1175, 830, 760

MS  $m/z$  192( $M^+$ ) 120, 107, 91, 43(100%)

5 **Step 2**

**Preparation of Compound 5 in Table 1**

5-(4-Heptylphenyl)benzo[b]furan-2-carboxylic acid (1.0 g, 3 mmol), prepared as described in Example 1 step 5 and the product of step 1 above (0.6 g, 3 mmol) were dissolved in dry DCM (100 ml) and DMAP (0.4 g, 3 mmol) was added, and the mixture stirred. DCC (0.6 g, 3 mmol) was then added, and stirring was continued (24 h). The reaction was monitored by tlc analysis. The precipitate of dicyclohexylurea was then filtered off, and the solvent removed *in vacuo*. The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C), DCM 7:3], followed by recrystallization (hexane).

15 A white solid was obtained.

Yield 0.8 g (52%). Purity (hplc) 99%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.91 (1H, dd), 7.75 (1H, d), 7.73 (1H, dd), 7.67 (1H, d), 7.54 (2H, d), 7.28 (2H, d), 7.25 (2H, d), 7.14 (2H, d), 2.65 (2h, t), 2.63 (2H, t), 1.64 (4H, m), 1.31 (16H, m), 0.88 (6H, t)

IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2920, 1734, 1578, 802

MS  $m/z$  510( $M^+$ ), 481, 425, 319(100%), 191

25 **Example 35**

**Preparation of 4-Butoxyphenyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate (Compound 7 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

30 5-(4-Heptylphenyl)benzo[b]furan-2-carboxylic acid (0.5 g, 1.5 mmol), 4-butoxyphenol (0.3 g, 1.5 mmol), DMAP (0.2 g, 1.5 mmol), DCC (0.3 g, 1.5 mmol). The product was obtained as a white, crystalline solid.

Yield 0.4 g (52%). Purity (hplc) >98%.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.89 (1H, dd), 7.75 (1H, s), 7.72 (1H, dd), 7.67 (1H, d), 7.54 (2H, d), 7.29 (2H, d), 7.17 (2H, d), 6.95 (2H, d), 3.98 (2H, t), 2.66 (2H, t), 1.79 (2H, qui), 1.66 (2H, qui) 1.49 (2H, qui), 1.32 (8H, m), 0.99 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2925, 1734, 1502, 1160, 948, 804

MS *m/z* 484(M<sup>+</sup>), 319, 264, 166, 69(100%)

10 **Example 36**

**Preparation of 4-Hexyloxyphenyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate (Compound 8 in Table 1)**

The title compound was prepared and purified in a similar manner to that described in Example 34 using the quantities stated.

15 5-(4-Heptylphenyl)benzo[b]furan-2-carboxylic acid (0.5 g, 1.5 mmol), 4-hexyloxyphenol (0.3 g, 1.5 mmol), DMAP (0.2 g, 1.5 mmol), DCC (0.3 g, 1.5 mmol). A white, crystalline solid was obtained.

Yield 0.3 g (40%). Purity (hplc) >99.9%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.93 (1H, dd), 7.77 (1H, d), 7.75 (1H, dd), 7.68 (1H, d) 7.56 (2H, d), 7.29 (2H, d), 7.16 (2H, d), 6.96 (2H, d) 3.98 (2H, t), 2.66 (2H t), 1.79 (2H, qui), 1.64 (2H, qui), 1.48 (2H, qui), 1.34 (12H, m), 0.93 (3H, t), 0.89 (3H, t)

25 IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2933, 2858, 1733, 1502, 1310, 1199, 1160, 1072, 948, 803

MS *m/z* 512(M<sup>+</sup>), 482, 427, 398, 178(100%)

**Example 37****Preparation of 4-Pentylphenyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate (Compound No. 66 in Table 1)**

The title compound was prepared and purified in a similar manner to that described in Example 34 using the quantities stated.

5-(4-Heptylphenyl)benzo[b]furan-2-carboxylic acid (0.5 g, 1.5 mmol), 4-pentylphenol (0.3 g, 1.5 mmol), DMAP (0.2 g, 1.5 mmol), DCC (0.3 g, 1.5 mmol).

A white, crystalline solid was obtained.

Yield 0.2 g (30%). Purity (hplc) 97.6%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.93 (1H, dd), 7.77 (1H, d), 7.75 (1H, dd), 7.69 (1H, d), 7.56 (2H, d), 7.30 (2H, d), 7.27 (2H, d), 7.15 (2H, d), 2.67 (2H, t), 2.64 (2H, t), 1.65 (4H, m), 1.33 (12H, m) 0.91 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2958, 2921, 2852, 1732, 1303, 1221, 1161, 803, 741

MS *m/z* 482(M<sup>+</sup>), 397, 319(100%), 263, 178

**Example 38****Preparation of (S)-(+)-4-(2-Methylbutyl)phenyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate (Compound 11 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

5-(4-Heptylphenyl)benzo[b]furan-2-carboxylic acid (0.5 g, 1.5 mmol), (S)-(+)-4-(2-methylbutyl)phenol (0.3 g, 1.5 mmol) DMAP (0.2 g, 1.5 mmol), DCC (0.3 g, 1.5 mmol).

A white, crystalline solid was obtained.

Yield 0.5 g (75%). Purity (hplc) 99.1%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.93 (1H, dd), 7.77 (1H, d), 7.75 (1H, dd), 7.69 (1H, d), 7.56 (2H, d), 7.29 (2H, d), 7.24 (2H, d), 7.16 (2H, d), 2.68(1H, dd), 2.66 (2H, t), 2.41 (1H, dd), 1.66 (3H, m), 1.32 (10H, m), 0.93 (3H, t), 0.89(3H, t), 0.87 (3H, d)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2965, 2858, 1735, 1569, 1502, 1294, 1075,

950, 807, 745

MS  $m/z$  482( $M^+$ ), 397, 319(100%), 267, 178

$[\alpha]_D^{25}$  +5.0° (0.01947 g/ml)

5 **Example 39**

**Preparation of (S)-(+)-1-Methylheptyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate (Compound 62 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

10 5-(4-Heptylphenyl)benzo[b]furan-2-carboxylic acid (0.5 g, 1.5 mmol), (S)-(+)-octan-2-ol (0.2 g, 1.5 mmol), DMAP (0.2 g, 1.5 mmol), DCC (0.3 g, 1.5 mmol).

A colourless oil was obtained.

Yield 0.5 g (74%). Purity (hplc) 99.7%.

15  $^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.85 (1H, dd), 7.68 (1H, dd), 7.61 (1H, d), 7.53 (1H, d) 7.52 (2H, d), 7.27 (2H, d), 5.17 (1H, m), 2.64 (2H, t), 1.75(2H, m), 1.62 (2H, m), 1.33 (19H, m), 0.88 (3H, t), 0.87 (3H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2929, 2856, 1719, 1539, 1461, 1245, 1165, 847, 803, 597

20 MS  $m/z$  448( $M^+$ ), 363, 336, 251, 57(100%)

$[\alpha]_D^{25}$  +43.3° (0.01878 g/ml)

**Example 40**

**Preparation of Preparation of Methyl 5-(4-heptylphenyl)benzo[b]furan-2-carboxylate (Compound 24 in Table 1)**

25 A mixture of compound Compound 43 in Table 1(0.1 g, 0.3 mmol) and sulphuric acid (conc.) (0.1 ml, 2.0 mmol) in methanol (5 ml) was refluxed (24 h) with exclusion of moisture. After allowing to cool, the mixture was poured into water (20 ml) and DCM added (20 ml) The separated aqueous layer was washed with DCM (2 x 20 ml). The combined organic layers were washed with water and brine, dried  
30 ( $\text{MgSO}_4$ ), and the solvent removed *in vacuo*. The product was purified by recrystallization (hexane).

A white crystalline solid was obtained.

Yield 0.1 g (95%). Purity (hplc) >99.5%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.88 (1H, d), 7.70 (1H, dd), 7.64 (1H, d), 7.57 (1H, d), 7.53 (2H, d), 7.28 (2H, d), 3.95 (3H, s), 2.66 (2H, s), 1.65 (2H, qui), 1.32 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2930, 2856, 1736, 1565, 1438, 1164, 1099, 898, 847, 767

MS *m/z* 350(M<sup>+</sup>), 293, 265(100%), 177, 165

#### **Example 41**

#### **10 Preparation of Ethyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate (Compound 64 in Table 1)**

Compound 64 was prepared and purified in a similar manner to that described for the preparation of compound 24 using the quantities stated.

Compound 63 in Table 1 (0.1 g, 0.3 mmol), sulphuric acid (conc.) (0.1 ml, 0.05 mmol), ethanol (5 ml).

Colourless needle-like crystals were obtained.

Yield 0.05 g (46%). Purity (hplc) >99%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.30 (1H, d), 7.99 (1H, dd), 7.79 (2H, d), 7.55 (1H, d), 7.30 (2H, d), 7.06 (1H, d), 3.67 (2H, q), 2.66 (2H, t), 1.65 (2H, qui), 1.14 (3H, t), 1.30 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 2856, 1708, 1616, 1509, 1445, 1172, 1019, 817

MS *m/z* 364(M<sup>+</sup>), 279, 251, 203, 91(100%),

#### **Example 42**

#### **25 Preparation of 4-Pentylphenyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate (Compound 65 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for the preparation of compound 5 in Table 1 in Example 34 using the quantities stated.

Compound 63 in Table 1 (0.3 g, 0.9 mmol), 4-pentylphenol (0.2 g, 0.9 mmol), DCC (0.2 g, 0.9 mmol), DMAP (0.1 g, 0.9 mmol).

Colourless crystals were obtained.

Yield 0.3 g (67%). Purity (hplc) 97.1%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.46 (1H, d), 8.12 (1H, dd), 7.81 (2H, d), 7.62 (1H, d), 7.31 (2H, d), 7.26 (2H, d), 7.13 (2H, d), 7.11 (1H, d), 2.67 (2H, t), 2.65 (2H, t), 1.65 (4H, qui), 1.32 (14H, m), 0.91 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2930, 2857, 1736, 1510, 1155, 1065, 913, 803, 761

MS *m/z* 482(M<sup>+</sup>), 397, 369, 319(100%), 205

10 **Example 43**

**Preparation of 4-Heptylphenyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate (Compound 19 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

15 Compound 63 in Table 1 (0.3 g, 0.9 mmol), 4-heptylphenol (0.2 g, 0.9 mmol), DCC (0.2 g, 0.9 mmol), DMAP (0.1 g, 0.9 mmol).

A white solid was obtained.

Yield 0.3 g (65%). Purity (hplc) 99.1%.

20 <sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.46 (1H, dd), 8.13 (1H, dd), 7.81 (2H, d), 7.62 (1H, d), 7.31 (2H, d), 7.26 (2H, d), 7.13 (2H, d), 7.11 (1H, d), 2.66 (2H, t), 2.65 (2H, t), 1.65 (4H, m), 1.32 (16H, m), 0.90 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 2857, 1737, 1510, 1465, 1156, 1065, 914, 838, 761

25 MS *m/z* 510(M<sup>+</sup>), 425, 318(100%), 220, 205

**Example 44**

**Preparation of 4-Butoxyphenyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate (Compound 20 in Table 1)**

30 The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

Compound 63 in Table 1 (0.3 g, 0.9 mmol), 4-butoxyphenol (0.2 g, 0.9 mmol), DCC (0.2 g, 0.9 mmol), DMAP (0.1 g, 0.9 mmol).

A white solid was obtained.

Yield 0.3 g (69%). Purity (hplc) >99%.

5  $^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  8.45 (1H, dd), 8.12 (1H, dd), 7.81 (2H, d), 7.62 (1H, d), 7.31 (2H, d), 7.13 (2H, d), 7.10 (1H, s), 6.94 (2H, d), 3.99 (2H, d), 2.67 (2H, t), 1.78 (2H, qui), 1.65 (2H, qui), 1.51 (2H, m), 1.30 (8H, m), 0.99 (3H, t), 0.86 (3H, t)

10  $\text{IR}$  (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2930, 2858, 1742, 1616, 1510, 1468, 1156, 1068, 913, 803, 761

$\text{MS } m/z$  484( $\text{M}^+$ ), 399, 319(100%), 206, 57

#### **Example 45**

##### **Preparation of 4-Hexyloxyphenyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate**

##### **(Compound 21 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

Compound 63 in Table 1 (0.3 g, 0.9 mmol), 4-hexyloxyphenol (0.2 g, 0.9 mmol), DCC (0.2 g, 0.9 mmol), DMAP (0.1 g, 0.9 mmol).

20 A white solid was obtained.

Yield 0.3 g (65%). Purity (hplc) >99%.

$^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  8.43 (1H, d), 8.10 (1H, dd), 7.79 (2H, d), 7.60 (1H, d), 7.29 (2H, d), 7.12 (2H, d), 7.08 (1H, s), 6.92 (2H, d), 3.96 (2H, t), 2.65 (2H, t), 1.77 (2H, qui), 1.63 (2H, qui), 1.46 (2H, qui), 1.30 (12H, m), 0.90 (3H, t), 0.87 (3H, t)

$\text{IR}$  (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2930, 2859, 1743, 1615, 1513, 1469, 1159, 1066, 916, 835, 803

$\text{MS } m/z$  512( $\text{M}^+$ ), 483, 427, 319(100%), 291

#### **Example 46**

##### **Preparation of (S)-(+)-4-(2-Methylbutyl)phenyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate (Compound 22 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

Compound 63 in Table 1 (0.3 g, 0.9 mmol), 4-(2-methyl-n-butyl)phenol (0.2 g, 0.9 mmol), DCC (0.2 g, 0.9 mmol), DMAP (0.1 g, 0.9 mmol).

5 White, fibrous crystals were obtained.

Yield 0.3 g (69%). Purity (hplc) 98.9%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.46 (1H, d), 8.13 (1H, dd), 7.81 (2H, d), 7.62 (1H, d), 7.31 (2H, d), 7.23 (2H, d), 7.13 (2H, h), 7.11 (1H, d), 2.69 (3H, m), 2.41 (1H, m), 1.66 (3H, m), 1.32 (10H, m), 0.93 (3H, t), 0.89 (3H, t), 0.88 (3H, d)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2933, 2858, 1728, 1509, 1124, 1064, 1015, 911, 835, 798, 760

MS m/z 482(M<sup>+</sup>), 397, 319(100%), 206, 57

[α]<sub>D</sub><sup>20</sup> +4.0° (0.01796 g/ml)

15 **Example 47**

**Preparation of (S)-(+)-1-Methylheptyl 2-(4-heptylphenyl)benzo[b]furan-5-carboxylate (Compound 23 in Table 1)**

The title compound was prepared and purified in a similar manner to that described for in Example 34 using the quantities stated.

20 Compound 63 in Table 1 (0.3 g, 0.9 mmol), octan-2-ol (0.1 g, 0.9 mmol), DCC (0.2 g, 0.9 mmol), DMAP (0.1 g, 0.9 mmol).

A white crystalline solid was obtained.

Yield 0.2 g (50%). Purity (hplc) 98.7%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.27 (1H, dd), 7.96 (1H, dd), 7.77 (2H, d), 7.52 (1H, d), 7.28 (2H, d), 7.04 (1H, d), 5.13 (1H, sxt), 2.64 (2H, t), 1.74 (2H, m), 1.61 (2H, m), 1.30 (19H, m), 0.87 (6H, m)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2933, 2861, 1715, 1595, 1507, 1163, 1087, 797, 765

MS m/z 448(M<sup>+</sup>), 336, 319, 251, 43(100%),



**Example 48****Preparation of 2,5-Bis-(4-heptylphenyl)benzo[b]furan (Compound 66 in Table 1)****Step 1:- Preparation of 5-(4-Heptylphenyl)benzo[b]furan**

The title compound was prepared in a similar manner to that described for the  
5 preparation of ethyl 5-(4-heptylphenyl)benzo{b}furan-2carboxylate in Example 1(4)  
using the quantities stated.

Compound 5-bromobenzofuran (10.0 g, 51 mmol), 4-heptylbenzene boronic acid (13.4  
g, 61 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol), sodium  
carbonate (13.5 g, 128 mmol). The product was purified by flash chromatography  
10 [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (petroleum  
fraction (bp 40-60 °C))

Colourless plates were obtained.

Yield 7.5 g (50%), mp 51-3 °C

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.77 (1H, d), 7.64 (1H, d), 7.55 (1H, d),  
15 7.53 (2H, d), 7.51 (1H, dd), 7.26 (2H, d), 6.81 (1H, d),  
2.65 (2H, t), 1.65 (2H, q), 1.34 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2921, 1463, 1130, 804, 743

MS m/z 292(M<sup>+</sup>), 220 207(100%), 178, 165,

**Step 2****20 Preparation of 5-(4-Heptylphenyl)benzo[b]furan-2-boronic acid**

The title compound was prepared in a similar manner to that described for the  
preparation of 4'-pentylbiphenylboronic acid in Example 20(2) using the quantities  
stated.

5-(4-Heptylphenyl)benzo[b]furan from step 1 (4.0 g, 13.7 mmol), n-butyllithium  
25 (2.5M in hexanes, 4.5 ml, 11.3 mmol), trimethyl borate (2.9 g, 27.4 mmol).

A pale-pink solid was obtained.

Yield 4.6 g (99%)

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.82 (1H, d), 7.59 (1H, dd), 7.55 (1H,  
d), 7.53 (2H, d), 7.41 (1H, d), 7.26 (2H, d), 4.94 (2H, s),  
30 2.65 (2H, t), 1.65 (2H, m), 1.33 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3400, 2930, 2850, 1575, 1445, 1330, 1010,

805

MS *m/z* 336( $M^+$ ), 292, 207(100%), 178, 107

**Step 3****Preparation of 2,5-Bis-(4-heptylphenyl)benzo[b]furan (Compound 66)**

5 Compound 66 was prepared in a similar manner to that described in Example 1(4) using the quantities stated.

5-(4-Heptylphenyl)benzo[b]furan-2-boronic acid (1.5 g, 4.5 mmol), 1-bromo-4-heptylbenzene, (0.8 g, 3.7 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol), sodium carbonate (1.0 g, 9.3 mmol).

10 The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C), DCM 9:1], followed by recrystallization (acetonitrile, toluene 5:1)

A colourless crystalline solid was obtained

Yield 0.4 g (26%). Purity (hplc) 98.6%.

15  $^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.78 (2H, d), 7.75 (1H, dd), 7.54 (2H, d), 7.53 (1H, d), 7.48 (1H, dd), 7.28(2H, d), 7.24 (2H, d), 7.03 (1H, d) 2.53 (4H, t), 1.52 (4H, m), 1.06 (16H, m), 0.57 (6H, t)

IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2920, 1465, 1160, 1015, 845, 800

MS *m/z* 466( $M^+$ ), (100%), 381, 309, 296, 252

20 **Example 49**

**Preparation of 5-(4-Heptylphenyl)-2-(4-pentylphenyl)-benzo[b]furan (Compound 67 in Table 1)**

25 The title compound was prepared and purified in a similar manner to that described for the preparation of compound 66 as described in Example 48 using the quantities stated.

5-(4-Heptylphenyl)benzo[b]furan-2-boronic acid (1.5 g, 4.5 mmol), 1-bromo-4-pentylbenzene, (0.8 g, 3.7 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol), sodium carbonate (1.0 g, 9.3 mmol).

A white crystalline solid was obtained.

30 Yield 0.4 g (20%). Purity (hplc) 98.5%.

$^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.80 (2H, d), 7.77 (1H, dd), 7.55 (2H,

d), 7.54 (1H, d), 7.50 (1H, dd), 7.29 (2H, d), 7.27 (2H, d), 7.05 (1H, d), 2.67 (2H, t), 2.66 (2H, t), 1.66 (4H, m), 1.33 (12H, m), 0.91 (3H, t), 0.89 (3H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2961, 2857, 1465, 908, 801

5 MS  $m/z$  438( $M^+$ ), 381, 353, 296(100%), 283

### **Example 50**

#### **Preparation of 2-(5-Heptylpyrimidin-2-yl)-5-(4-heptylphenyl)benzo[b]furan (Compound 68 in Table 1)**

The title compound was prepared and purified in a similar manner to that described in Example 1(4) using the quantities stated.

5-(4-Heptylphenyl)benzo[b]furan-2-boronic acid (1.5 g, 4.5 mmol), 2-chloro-5-heptylpyrimidine (0.8 g, 3.7 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol), sodium carbonate (1.0 g, 9.3 mmol).

The product was purified by flash chromatography [silica gel / petroleum fraction (bp 15 40-60 °C), DCM 1:1], followed by recrystallization (hexane).

Colourless needles-like crystals were obtained.

Yield 0.8 g (46%). Purity (hplc) >99.9%.

$^1\text{H}$  NMR  $\text{CDCl}_3/\delta$  8.67 (2H, s), 7.85 (1H, d), 7.69 (1H, d), 7.69 (1H, d), 7.60 (1H, dd), 7.55 (2H, d), 7.28 (2H, d), 2.68 (4H, t), 1.67 (4H, m), 1.34 (16H, m), 0.89 (6H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2923, 2852, 1577, 1542, 1425, 1153, 804, 795

MS  $m/z$  468( $M^+$ ), 383(100%), 311, 298, 232

### **Example 51**

#### **Preparation of 2-(3,4-Difluorophenyl)-5-(4-heptylphenyl)benzo[b]furan (Compound 69 in Table 1)**

The title compound was prepared and purified in a similar manner to that described in Example 1(4) using the quantities stated.

5-(4-Heptylphenyl)benzo[b]furan-2-boronic acid (0.4 g, 1.2 mmol), 1-bromo-3,4-difluorobenzene, (0.2 g, 1.1 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol), sodium carbonate (1.0 g, 9.3 mmol).

The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (ethanol).

Colourless crystals were obtained.

Yield 0.1 g (12%). Purity (hplc) 98%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.79 (1H, dd), 7.72 (1H, ddd), 7.65 (1H, m), 7.58 (2H, d), 7.57 (1H, d), 7.54 (1H, dd), 7.29 (1H, m), 7.28 (1H, m), 7.08 (1H, s), 2.66 (2H, t), 1.65 (2H, qui), 1.32 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2925, 2857, 1515, 1468, 1180, 874, 798,

772

MS *m/z* 707(M<sup>+</sup>), 319(100%), 305, 289, 159

## 10 **Example 52**

### **Preparation of 2-(2,3-Difluoro-4-heptylphenyl)-5-(4-heptylphenyl)benzo[b]furan (Compound 70 in Table 1)**

#### **Step 1**

#### **Preparation of 1-(2,3-Difluorophenyl)heptan-1-ol**

15 n-Butyllithium (2.5M in hexanes, 140.0 ml, 350.0 mmol) was added dropwise to a cooled (-78°C) solution of *O*-difluorobenzene (40.0 g, 350.0 mmol) in dry THF (400 ml) with stirring under nitrogen. Stirring at low temperature was continued (1½ h) and n-heptanal (40.1 g, 333.0 mmol) was added dropwise. The mixture was allowed to return to room temperature overnight with stirring under nitrogen. 2M

20 hydrochloric acid (225 ml) was added and stirring was continued (1 h). The mixture was then poured into water (400 ml) and ether added (200 ml). The separated aqueous layer was washed with ether (2 x 300 ml). The combined ethereal layers were washed with water and brine and dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The residue was then distilled.

25 A pale-yellow oil was obtained.

Yield 63.1 g (83%) bp 140 °C at 0.001 mmHg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.24 (1H, m), 7.10 (2H, m), 5.00 (1H, t),  
2.25 (1H, s), 1.75 (2H, m), 1.30 (8H, m), 0.88 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3369, 2931, 1626, 1596, 1484, 1278, 1203,

30 1061, 786, 726

MS *m/z* 228(M<sup>+</sup>), 211, 199, 143(100%), 127

**Step 2****Preparation of 1-(2,3-Difluorophenyl)hept-1-ene**

Phosphorus pentoxide (94.9 g, 669.0 mmol) was carefully added to a solution of 1-(2,3-Difluorophenyl)heptan-1-ol (61.1 g, 267.0 mmol) from step 1 in pentane (90 ml) and the mixture was stirred overnight with exclusion of moisture. When glc  
 5 analysis revealed a complete reaction, the mixture was poured into ice/water (300 ml) and ether added (200 ml). The separated aqueous layer was washed with ether (2 x 300 ml). The combined organic layers were washed with water and brine and dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The residue was then distilled.

10 A colourless oil was obtained.

Yield 30.9 g (55%) bp 95 °C at 0.05 mmHg.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.16 (1H, m), 6.97 (2H, m), 6.51 (1H, d), 6.34 (1H, dt) 2.23 (2H, q), 1.48 (2H, qui), 1.34 (4H, m), 0.91 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 1621, 1589, 1482, 1205, 972, 773,

15

712

MS *m/z* 210(M<sup>+</sup>), 167, 153, 140(100%), 127

**Step 3****Preparation of 1,2-Difluoro-3-heptylbenzene**

A mixture of the product of step 2 (30.5 g, 145 mmol) and palladium-on-charcoal (10% w/w, 1.0 g, 0.9 mmol) in ethanol (400 ml) was stirred in an atmosphere  
 20 of hydrogen (glc analysis revealed a complete reaction). The mixture was then filtered through a pad of 'Hyflo Supercel' and the solvent was removed *in vacuo*. The product was purified by distillation.

A pale yellow liquid was obtained.

25

Yield 26.4 g (86%) bp 95 °C at 0.003 mmHg.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 6.95 (3H, m), 2.65 (2H, t), 1.60 (2H, qui), 1.31 (8H, m), 0.88 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 2858, 1628, 1595, 1490, 1209, 822, 780, 725

30

MS *m/z* 212(M<sup>+</sup>), 141, 127(100%), 114, 83

**Step 4****Preparation of 2,3-Difluoro-1-iodo-4-heptylbenzene**

n-Butyllithium (2.5M in hexanes, 14.4 ml, 36.0 mmol) was added dropwise to a cooled (-78°C) solution of the product of step 3 (7.0 g, 33.0 mmol) in dry THF (100 ml) with stirring under nitrogen. Stirring at low temperature was continued (1 h) and iodine (8.4 g, 33.0 mmol) in dry THF (100 ml) was added dropwise, maintaining low temperature. The mixture was allowed to return to room temperature overnight with stirring under nitrogen. It was then poured into water (50 ml) and ether added (50 ml). The separated aqueous layer was washed with ether (2 x 50 ml) and the combined organic layers were washed with saturated aqueous sodium sulphite, water and brine, and dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*.

The product was purified by distillation.

A pale-pink liquid was obtained.

Yield 5.0 g (45%) bp 125 °C at 0.005 mmHg.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.37 (1H, ddd), 6.73 (1H, ddd), 2.63 (2H, dt), 1.58 (2H, t), 1.29 (8H, m), 0.88 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2927, 2856, 1457, 1285, 866, 806, 724, 612, 546

MS *m/z* 338(M<sup>+</sup>), 254, 139, 127(100%), 107

**Step 5****Preparation of 2-(2,3-Difluoro-4-heptylphenyl)-5-(4-heptylphenyl)benzo[b]furan**

Compound 70 in Table 1 was prepared in a similar manner to that described for the preparation of compound 66 in Example 48(3) using the quantities stated. 5-(4-Heptylphenyl)benzo[b]furan-2-boronic acid (0.6 g, 1.8 mmol), the product of step 4 (0.6 g, 1.6 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol), sodium carbonate (0.4 g, 4.0 mmol). The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (hexane).

A white crystalline solid was obtained.

Yield 0.3 g (37%). Purity (hplc) >99%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.81 (1H, dd), 7.69 (1H, ddd), 7.57 (2H,

m), 7.56 (2H, d), 7.28 (2H, d), 7.25 (1H, dd), 7.10 (1H, ddd), 2.72 (2H, t), 2.66 (2H, t), 1.65 (4H, qui), 1.33 (16H, m), 0.89 (6H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2927, 2856, 1498, 1123, 965, 878, 809,

5 726

MS  $m/z$  502( $M^+$ )(100%), 417, 332, 166, 58

### **Example 53**

#### **Preparation of 2-(Hept-1-ynyl)-5-(4-heptylphenyl)benzo[b]furan (Compound 17 in Table 1)**

##### 10 **Step 1**

#### **Preparation of 2-Iodo-5-(4-heptylphenyl)benzo[b]furan**

n-Butyllithium (2.5M in hexanes, 3.8 ml, 9.4 mmol) was added dropwise to a cooled ( $-10^{\circ}\text{C}$ ) solution of 5-(4-Heptylphenyl)benzo[b]furan (2.5 g, 8.6 mmol) (prepared as described in Example 48(1) in dry THF (100 ml) with stirring under  
15 nitrogen. Stirring at low temperature was continued (2 h), and iodine (4.3 g, 17.2 mmol) in dry ether (30 ml) was added dropwise. After stirring at low temperature for a further 30 min the mixture was allowed to return to room temperature. It was then poured into water (50 ml) and ether added (50 ml). The separated aqueous layer was washed with ether (2 x 50 ml). The combined ethereal layers were washed with  
20 saturated aqueous sodium sulphite, water and brine, and dried ( $\text{MgSO}_4$ ). The solvent was removed *in vacuo*. The product was purified by recrystallization (hexane). Colourless plate-like crystals were obtained.

Yield 2.5 g (70%), mp  $94-95^{\circ}\text{C}$

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.71 (1H, d), 7.52 (1H, d), 7.51 (2H, d), 7.46 (1H, dd),  
25 7.04 (1H, d), 2.65 (2H, t), 1.64 (2H, qui), 1.31 (8H, m), 0.89 (3H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2922, 2849, 1524, 1446, 1232, 1147, 1048,

918, 897, 884, 668

MS  $m/z$  418( $M^+$ ), 333, 207, 178, 43(100%),

##### 30 **Step 2**

**Preparation of 2-(Hept-1-ynyl)-5-(4-heptylphenyl)benzo[b]furan**

n-Butyllithium (2.5M in hexanes, 2.8 ml, 6.9 mmol) was added dropwise to a cooled (-40°C) solution of hept-1-yne (0.6 g, 6.3 mmol) in dry THF (17 ml) with stirring under nitrogen. Stirring at low temperature was continued (20 min), and a solution of anhydrous zinc chloride (1.1 g, 8.0 mmol) in dry THF (30 ml) was added dropwise, maintaining low temperature. Stirring under nitrogen was continued (4 h) and the mixture was allowed to return to room temperature. The product of step 1 (2.4 g, 5.7 mmol) and tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol) were added, and the mixture was heated (70 °C) with stirring under nitrogen (12 h). When glc/tlc analysis revealed no further reaction the mixture was poured into water (50 ml) and ether added (50 ml). The separated aqueous layer was washed with ether (2 x 50 ml). The combined organic layers were washed with water and brine and dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)].

A yellow crystalline solid was obtained.

Yield 0.9 g (42%). Purity (hplc) 99.5%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.72 (1H, d), 7.54 (1H, dd), 7.53 (2H, d), 7.47 (1H, d), 7.27 (2H, d), 6.88 (1H, s), 2.65 (2H, t), 2.51 (2H, t), 1.67 (4H, m), 1.40 (12H, m), 0.95 (3H, t), 0.90 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 2859, 2210, 1570, 1265, 992, 886, 842, 749, 727

MS m/z 386(M<sup>+</sup>), 371, 301(100%), 244, 207

**Example 54****Preparation of 2-(4-heptylphenyl)-5-(hept-1-ynylphenyl)benzo[b]furan****(Compound 71 in Table 1)****Step 1**

Preparation of 5-(Hept-1-ynylphenyl)benzo[b]furan )

The title compound was prepared and purified in a similar manner to that described for the preparation of compound 17 in Example 53 using the quantities stated. n-Butyllithium (2.5M in hexanes, 4.8 ml, 12.0 mmol), hept-1-yne (1.1 g, 11.0 mmol), zinc chloride (1.9 g, 14.0 mmol), 4-bromobenzofuran (2.0 g, 10.0 mmol).

A yellow liquid was obtained.



Yield 1.2 g (57%)

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.65 (2H, d), 7.42 (1H, d), 7.33 (1H, dd), 6.76 (1H, dd),  
2.42 (2H, t), 1.63 (2H, qui), 1.41 (4H, m), 0.94 (3H, t)

IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2936, 2866, 1465, 1131, 1032, 883, 768,

5 735

MS  $m/z$  212( $\text{M}^+$ ), 197, 183, 169, 154(100%)

## **Step 2**

### **Preparation of 5-(Hept-1-ynylphenyl)benzo[b]furan-2-boronic acid**

The title compound was prepared in a similar manner to that described in

10 Example 20(2) using the quantities stated.

5-(Hept-1-ynylphenyl)benzo[b]furan ) from step 1 (1.0 g, 5.2 mmol), n-butyllithium (2.5M in hexanes, 2.3 ml, 5.7 mmol), trimethyl borate (1.2 g, 11.4 mmol).

An orange solid was obtained.

Yield 1.0 g (83%)

15 MS  $m/z$  232( $\text{M}^+$ ), 212, 183, 169, 155(100%)

## **Step 3**

### **Preparation of 2-(4-heptylphenyl)-5-(hept-1-ynylphenyl)benzo[b]furan (Compound 71 in Table 1)**

The title compound was prepared and purified in a similar manner to that  
20 described for the preparation of compound 70 in Example 52 using the quantities stated. 5-(Hept-1-ynylphenyl)benzo[b]furan-2-boronic acid from step 2 (1.0 g, 4.3 mmol), 1-bromo-4-heptylbenzene (Example 1(1)) (1.1 g, 4.3 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol), sodium carbonate (1.1 g, 11.0 mmol).

25 Yield 0.3 g (18%). Purity (hplc) 85.1%.

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.76 (2H, d), 7.61 (1H, d), 7.42 (1H, d), 7.29 (1H, dd),  
7.28 (2H, d), 6.96 (1H, s), 2.65 (2H, t), 2.42 (2H, t), 1.63 (4H, qui), 1.35 (12H, m), 0.94 (3H, t), 0.89 (3H, t)

IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2935, 2859, 1906, 1700, 1653, 1636, 1467,

30 1274, 878, 798

MS  $m/z$  386 ( $\text{M}^+$ )(100%), 343, 301, 244, 215

**Example 55****Preparation of 2-(4-Heptylphenyl)-5-(4-pentylphenyl)benzo[b]furan (Compound 72 in Table 1)****Step 1****5 Preparation of 1-Heptyl-4-iodobenzene**

The title compound was prepared and purified in a similar manner to that described in Example 1(1) using the quantities stated.

Iodobenzene (20.4 g, 100 mmol), n-heptanoyl chloride (17.8 g, 120 mmol), aluminium chloride (14.7 g, 110 mmol), poly(methylhydrosiloxane) (16.1 g 267  
10 mmol).

The compound was prepared and stored under exclusion of light.

A pale-yellow liquid was obtained.

Yield 12.2 g (40%) bp 120 °C at 0.005 mmHg (lit.<sup>2</sup> 165°C at 10 mmHg).

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.60 (2H, d), 6.96 (2H, d), 2.51 (2H, t), 1.60 (2H, m),  
15 1.35-1.25 (8H, m), 0.90 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2926, 2854, 1466, 1062, 995, 794

MS m/z 302(M<sup>+</sup>)(100%), 259, 231, 217, 127

**Step 2****Preparation of 2-(4-Heptylphenyl)-5-bromobenzo[b]furan**

20 The title compound was prepared in a similar manner to that described in Example 1(4) using the quantities stated.

1-Heptyl-4-iodobenzene from step 1 (2.1 g, 7.0 mmol), 4-bromobenzo[b]furan-2-boronic acid (2.0 g, 8.0 mmol), sodium carbonate (1.9 g, 18.0 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol)

25 The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (hexane).

A white solid was obtained.

Yield 0.5 g (20%), mp 144-149 °C

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.68 (2H, d), 7.62 (1H, d), 7.32 (1H, d),  
30 7.28 (1H, dd), 7.20 (2H, d), 6.87 (1H, s), 2.57 (2H, t),  
1.56 (2H, t), 1.23 (8H, m), 0.80 (3H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2930, 2858, 1609, 1582, 1035, 922, 895,

670, 505

MS  $m/z$  372, 370( $M^+$ ), 285(100%), 205, 176, 152

### **Step 3**

#### **5 Preparation of 2-(4-Heptylphenyl)-5-(4-pentylphenyl)benzo[b]furan (Compound 72 in Table 1)**

The title compound was prepared in a similar manner to that described in Example 1(4) using the quantities stated.

2-(4-Heptylphenyl)-5-bromobenzo[b]furan (0.4 g, 1.1 mmol), 4-pentylbenzeneboronic  
10 acid (0.3 g, 1.3 mmol), sodium carbonate (0.3 g, 2.8 mmol),  
tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol)

The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (hexane).

A white crystalline solid was obtained.

15 Yield 0.4 g (83%). Purity (hplc) 98.4%.

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.79 (2H, d), 7.77 (1H, d), 7.56 (1H, d), 7.55 (2H, d),  
7.50 (1H, dd), 7.30 (2H, d), 7.28 (2H, d), 7.05 (1H, s),  
2.66 (4H, t) 1.66 (4H, m), 1.33 (12H, m), 0.92 (3H, t),  
0.89 (3H, t)

20 IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2963, 2928, 2858, 1589, 1121, 1034, 884,

799

MS  $m/z$  438( $M^+$ ), 381, 353, 296, 43(100%)

### **Example 56**

#### **Preparation of Compound 73 in Table 1**

#### **25 Step 1**

#### **Preparation of 1-Heptyl-2,3-difluorobenzene-4-boronic acid**

The title compound was prepared in a similar manner to that described for the preparation of 4'-pentylbiphenylboronic acid in Example 20(2) using the quantities stated.

30 1,2-Difluoro-3-heptylbenzene prepared as described in Example 52(3) (19.2 g, 90.0 mmol), n-butyllithium (2.5M in hexanes, 39.8 ml, 99.0 mmol), trimethyl borate (18.7 g, 180.0 mmol).

A white solid was obtained.

Yield 19.9 g (87%)

<sup>1</sup>H NMR DMSO-d<sup>6</sup>/δ 7.11 (1H, m), 7.10 (1H, m), 2.62 (2H, dt), 1.54 (2H, qui),  
1.24 (8H, m), 0.84 (3H, t) (acidic proton was not shown)

5 IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3661, 3342, 2939, 2849, 1628, 1425, 1190,  
929, 902, 835, 723

MS m/z 212(M<sup>+</sup>-B(OH)<sub>2</sub>+H), 169, 140, 128(100%), 101

## **Step 2**

### **Preparation of 5-(2,3-Difluoro-4-heptylphenyl)benzo[b]furan**

10 The title compound was prepared in a similar manner to that described in  
Example 1(4) using the quantities stated.

4-bromobenzofuran (1.8 g, 9.0 mmol), 1-Heptyl-2,3-difluorobenzene-4-boronic acid  
from step 1 (2.8 g, 10.8 mmol), sodium carbonate (2.4 g, 23.0 mmol),  
tetrakis(triphenylphosphine)palladium(0) (0.3 g, 0.3 mmol)

15 The product was purified by flash chromatography [silica gel / petroleum fraction (bp  
40-60 °C)], followed by recrystallisation (hexane).

A pale-yellow liquid was obtained.

Yield 1.4 g (47%)

20 <sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.77 (1H, s), 7.70 (1H, d), 7.58 (1H, dd), 7.46 (1H, ddd),  
7.16 (1H, ddd), 7.04 (1H, ddd), 6.85 (1H, d), 2.71 (2H,  
t), 1.66 (2H, qui), 1.38 (8H, m), 0.91 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2933, 2861, 1468, 1113, 890, 808, 772,  
739

MS m/z 328(M<sup>+</sup>), 243, 231, 194, 43(100%)

## 25 **Step 3**

### **Preparation of 5-(2,3-Difluoro-4-heptylphenyl)benzo[b]furan-2-boronic acid**

The title compound was prepared in a similar manner to that described for the  
preparation of 4'-pentylbiphenylboronic acid in Example 20(2) using the quantities  
stated.

30 The product of step 2 (1.2 g, 3.7 mmol), n-butyllithium (2.5M in hexanes, 1.6 ml, 4.0  
mmol), trimethyl borate (0.8 g, 7.4 mmol).

A white solid was obtained.

Yield 1.1 g (80%)

MS  $m/z$  328( $M^+ - B(OH)_2$ ), 256, 243(100%), 201, 175

**Step 4**

5 **Preparation of 5-(2,3-Difluoro-4-heptylphenyl)-2-(4-heptylphenyl)-benzo[b]furan**  
**(Compound 73 in Table 1)**

The title compound was prepared in a similar manner to that described for the preparation of in Example 1(4) using the quantities stated.

1-bromo-4-heptylbenzene (0.8 g, 3.0 mmol), 5-(2,3-Difluoro-4-  
10 heptylphenyl)benzo[b]furan-2-boronic acid) from step 3 (1.1 g, 3.0 mmol), sodium carbonate (0.8 g, 8.0 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol).

A white, fibrous, crystalline solid was obtained.

Yield 0.4 g (27%). Purity (hplc) 98.4%.

15  $^1H$  NMR  $CD_2Cl_2/\delta$  7.80 (2H, d), 7.73 (1H, m), 7.58 (1H, d), 7.43 (1H, ddd),  
7.30 (2H, d), 7.18 (1H, m), 7.05 (1H, d), 7.04 (1H, m),  
2.71 (2H, t), 2.66 (2H, t), 1.66 (4H, m), 1.33 (16H, m),  
0.90 (3H, t), 0.89 (3H, t)

IR (KBr)  $\nu_{max}/cm^{-1}$  2936, 2856, 1509, 1121, 1033, 916, 802,

20 754

MS  $m/z$  502( $M^+$ ), 417, 332, 224, 91(100%)

**Example 57**

**Preparation of Compound 74 in Table 1**

**Step 1**

25 **Preparation of 5-(5-Heptylpyrimidin-2-yl)benzo[b]furan**

The title compound was prepared and purified in a similar manner to that described for the preparation of compound 68 in Table 1 using the quantities stated.

Benzo[b]furan-5-boronic acid (Example 22(1)) (0.7 g, 4.2 mmol), 2-chloro-5-  
heptylpyrimidine (0.8 g, 3.7 mmol) tetrakis(triphenylphosphine)palladium(0) (0.1 g,  
30 0.1 mmol), sodium carbonate (0.9 g, 8.8 mmol).

A pale-yellow, waxy solid was obtained

Yield 0.9 g (83%)

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 8.69 (1H, d), 8.62 (2H, s), 8.42 (1H, dd), 7.65 (1H, d),  
7.58 (1H, d), 6.84 (1H, dd), 2.61 (2H, t), 1.65 (2H, qui),  
1.31 (8H, m), 0.87 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2928, 2856, 1588, 1547, 1130, 1029, 796,

5 768, 737

MS m/z 294(M<sup>+</sup>), 265, 251, 223, 209(100%)

## **Step 2**

### **Preparation of 5-(5-Heptylpyrimidin-2-yl)benzo[b]furan-2-boronic acid**

n-Butyllithium (2.5M in hexanes, 2.0 ml, 5.1 mmol) was added dropwise to a  
10 cooled (-70 °C) solution of dry diisopropylamine (2.0 g, 20.0 mmol) in dry THF (15  
ml) with stirring under nitrogen. Stirring was continued (10 min), and 5-(5-  
Heptylpyrimidin-2-yl)benzo[b]furan from step 1(1.5 g, 5.1 mmol) in dry THF (7 ml)  
was added dropwise at -70°C. After stirring under nitrogen (1 h) trimethyl borate (1.0  
g, 10.0 mmol) was added dropwise at low temperature. The system was allowed to  
15 return to room temperature overnight whilst stirring under nitrogen. Hydrochloric acid  
(5M, 4.0 ml) was added with stirring. The mixture was then poured into water (100  
ml) and ether added (50 ml). The separated aqueous layer was washed with ether (3 x  
50 ml). The combined organic layers were washed with water and brine, and dried  
(MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The residue was adsorbed onto silica  
20 and washed with petroleum fraction (bp 40-60 °C). The adsorbate was then washed  
with THF, and the solvent removed *in vacuo*.

An orange solid was obtained.

Yield 1.4 g (78%)

MS m/z 294(M<sup>+</sup>-B(OH)<sub>2</sub>), 223, 209(100%), 195, 181

## 25 **Step 3**

### **Preparation of 2-(2,3-Difluoro-4-heptyl)-5-(5-heptylpyrimidin-2-yl)benzo[b]furan (Compound 74)**

The title compound was prepared in a similar manner to that described for the  
preparation of compound 68 in Table 1 using the quantities stated.  
30 5-(5-Heptylpyrimidin-2-yl)benzo[b]furan-2-boronic acid from step 2 (1.3 g, 3.8  
mmol), 2,3-Difluoro-1-iodo-4-heptylbenzene (Example 52 (4) (1.5 g, 4.6 mmol),

tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol), sodium carbonate (1.2 g, 12.0 mmol). The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C), DCM 7:3], followed by recrystallisation (ethanol, DCM 9:1), and finally, by preparative hplc (acetonitrile, chloroform 4:1).

5 Colourless needle-like crystals were obtained.

Yield 0.4 g (17%). Purity (hplc) >99.9%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.71 (1H, d), 8.62 (2H, s), 8.44 (1H, dd), 7.68 (1H, ddd),  
7.59 (1H, d), 7.27 (1H, dd), 7.09 (1H, ddd), 2.70 (2H, t),  
2.62 (2H, t), 1.66 (2H, qui), 1.64 (2H, t), 1.36-1.24 (16H,  
10 m),  
0.87 (6H, t)

IR (KBr)  $\nu_{\text{max}}$ /cm<sup>-1</sup> 2932, 2859, 1586, 1549, 1328, 1117, 964,  
875, 797

MS *m/z* 504(M<sup>+</sup>)(100%), 462, 433, 419, 321

15 **Example 58**

**Preparation of Compound 75 in Table 1**

**Step 1**

**Preparation of 1,2-Difluorobenzene-3-boronic acid**

The title compound was prepared in a similar manner to that described in  
20 Example 20(2) using the quantities stated.  
O-difluorobenzene (65.8 g, 577.0 mmol), n-butyllithium (2.5M in hexanes, 231.0 ml,  
577.0 mmol), trimethyl borate (71.9 g, 692.0 mmol).  
The reaction mixture was poured into water (200 ml) and ether added (200 ml). The  
separated aqueous phase was washed with ether (3 x 200 ml). The product was  
25 extracted from the combined ethereal phases as the potassium salt by washing with  
potassium hydroxide (2M, 290 ml). The basic solution was then washed with ether,  
and the product released by acidification to pH3 by adding hydrochloric acid (conc.) to  
the aqueous solution. The product was then extracted with ether (3 x 200 ml). The  
combined organic layers were washed with water and brine, dried (MgSO<sub>4</sub>), and the  
30 solvent removed *in vacuo*.

A white solid was obtained. Yield 47.1 g (52%)

MS *m/z* 420 (3M<sup>+</sup>-3H<sub>2</sub>O)(100%), 280, 140, 94, 75

**Step 2****Preparation of 2,3-Difluorophenol**

Hydrogen peroxide (100 vol, 197.0 ml, 1.74 mol) was added slowly to a stirred solution of 1,2-difluorobenzene-3-boronic acid (458. g, 290.0 mmol) in dry diethyl ether (300 ml) and the mixture was refluxed (2 h). After allowing to cool, the mixture was washed with ether (3 x 250 ml). The combined ethereal layers were washed with saturated aqueous sodium thiosulphate, water and brine and dried (MgSO<sub>4</sub>), and the solvent removed *in vacuo*. The product was purified by distillation. A colourless liquid was obtained, which solidified on cooling.

Yield 24.2 g (64%) bp 150 °C at 760 mmHg.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 6.95 (1H, m), 6.75 (2H, m), 4.95 (1H, s)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3187, 2986, 1623, 1534, 1196, 1023, 889, 773, 701

MS *m/z* 130(M<sup>+</sup>)(100%), 101, 82, 71, 56

**Preparation of 4-Bromo-2,3-difluorophenol**

Bromine (29.1 g, 182.0 mmol) in glacial acetic acid (45 ml) was carefully added dropwise, maintaining low temperature, to a vigorously stirred, cooled (10 °C) solution of 2,3-difluorophenol (21.4 g, 165.0 mmol) in glacial acetic acid / chloroform 4:1 (55 ml). Stirring was continued (15 min) and the mixture was poured into water (200 ml) and DCM added (100 ml). The separated aqueous layer was washed with DCM (3 x 100 ml), and the combined organic layers were washed with saturated aqueous sodium bicarbonate, water and brine and dried (MgSO<sub>4</sub>). The solvent was then removed *in vacuo*. Hexane (100 ml) was added to the residue and the mixture was heated until homogeneous. It was then cooled (8 °C) and the solvent was removed by filtration. The product was then distilled.

A colourless liquid was obtained.

Yield 26.7 g (77%) bp 135-160 °C at 20 mmHg.

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.22 (1H, m), 6.71 (1H, m), 5.57 (1H, s)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3395, 2970, 1622, 1187, 1032, 876, 798, 630, 535

MS *m/z* 210,208(M<sup>+</sup>), 179, 128, 101, 81(100%)



NMR revealed approximately 33% impurity, consisting of starting material and dibromination product. Further purification was carried out after the next synthetic step.

5 **Step 4**

**Preparation of 2-(4-Bromo-2,3-difluorophenoxy)acetaldehyde dimethyl acetal**

The title compound was prepared in a similar manner to that described in Example 9(1) using the quantities stated.

The product of step 3 (28.6 g, 137.0 mmol), bromoacetaldehyde dimethyl acetal (25.5 g, 151.0 mmol), potassium carbonate (37.9 g, 274.0 mmol) and potassium iodide (1.1 g, 7.0 mmol).

The crude product was purified by flash chromatography [neutral alumina / petroleum fraction (bp 40-60 °C), DCM 10:3], followed by distillation.

A colourless liquid was obtained.

15 Yield 17.4 g (46%) bp 127 °C at 0.05 mmHg.

$^1\text{H NMR}$   $\text{CDCl}_3/\delta$  7.21 (1H, m), 6.70 (1H, m), 4.71 (1H, t), 4.05 (2H, d),  
3.47 (6H, s)

$\text{IR}$  (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2945, 2842, 1619, 1504, 1140, 880, 795,  
593

20  $\text{MS } m/z$  298, 296( $\text{M}^+$ ), 265, 235, 207, 75(100%)

**Step 5**

**Preparation of 5-Bromo-6,7-difluorobenzo[b]furan**

The title compound was prepared and purified in a similar manner to that described for the preparation of 5-bromobenzo[b]furan in Example 9(2) using the  
25 quantities stated.

The product of step 4 (9.7 g, 33.0 mmol), polyphosphoric acid (13.9 g).

The product was further purified by recrystallization (ethanol).

White needle-like crystals were obtained.

Yield 1.9 g (25%), mp 96.5-98.0 °C

30  $^1\text{H NMR}$   $\text{CD}_2\text{Cl}_2/\delta$  7.73 (1H, d), 7.58 (1H, dd), 6.80 (1H,  
dd)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  1603, 1485, 1125, 1084, 876, 814, 765,

730, 640, 531

MS  $m/z$  234, 232 ( $M^+$ ), 153, 125, 105(100%), 77

### **Step 6**

#### **5 Preparation of 5-Bromo-6,7-difluorobenzo[b]furan-2-boronic acid**

The title compound was prepared and purified in a similar manner to that described for the preparation of 5-(5-Heptylpyrimidin-2-yl)benzo[b]furan-2-boronic acid (Example 57(2)) using the quantities stated.

n-Butyllithium (2.5M in hexanes, 5.2 ml, 13.0 mmol) dry diisopropylamine (1.3 g, 13.0 mmol), the product of step 5 (3.0 g, 13.0 mmol), trimethyl borate (2.7 g, 26.0 mmol),

hydrochloric acid (5M, 5.2 ml).

A cream-coloured solid was obtained.

Yield 3.1 g (86%)

15 MS  $m/z$  777, 775 ( $3M^+ - 3H_2O$ ), 705(100%), 626, 231, 124

### **Step 7**

#### **Preparation of 5-Bromo-6,7-difluoro-2-(4-pentylphenyl)benzo[b]furan**

The title compound was prepared and purified in a similar manner to that described for the preparation of 5-(4-pentylphenyl)benzo[b]furan (Example 24 (1)) using the quantities stated.

4-Iodo-4-pentylbenzene (Example 22(2)) (1.8 g, 6.7 mmol), the product of step 6 (1.6 g, 5.6 mmol), sodium carbonate (1.8 g, 17.0 mmol),

tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol)

A white, crystalline solid was obtained.

25 Yield 1.2 g (57%), mp 62-64 °C

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.76 (2H, d), 7.54 (1H, dd), 7.30 (2H, d), 6.96 (1H, d),  
2.66 (2H, t), 1.65 (2H, qui), 1.34 (4H, m), 0.90 (3H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2932, 2866, 1605, 1442, 1043, 909, 795,

548

30 MS  $m/z$  380, 378 ( $M^+$ ), 321(100%), 241, 213, 193

**Step 8****Preparation of 6,7-Difluoro-5-(4-heptylphenyl)-2-(4-pentylphenyl)benzo[b]furan (Compound 75 in Table 1)**

The title compound was prepared in a similar manner to that described in Example 1(4) using the quantities stated.

Product of step 7 (1.2 g, 3.2 mmol), 4-heptylbenzeneboronic acid (0.9 g, 3.8 mmol), sodium carbonate (0.9 g, 8.0 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol)

The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (ethanol). It was then dissolved in carbon tetrachloride/chloroform 19:1. The solution was triturated with methanol, the precipitate filtered, and washed with ethanol.

Colourless, needle-like crystals were obtained.

Yield 0.4 g (23%). Purity (hplc) 99%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.79 (2H, d), 7.47 (2H, d), 7.34 (1H, dd), 7.31 (2H, d), 7.30 (2H, d), 7.02 (1H, d), 2.67 (2H, t), 2.66 (2H, t), 1.66 (4H, qui), 1.37-1.26 (12H, m), 0.91 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2960, 2857, 1613, 1513, 1160, 1038, 910, 838, 807, 661

MS m/z 474(M<sup>+</sup>)(100%), 417, 389, 331, 232

**Example 59****Preparation of 6,7-Difluoro-2-(2,3-difluoro-4-heptylphenyl)-5-(4-heptylphenyl)benzo[b]furan (Compound 76 in Table 1)****Step 1****Preparation of 5-Bromo-6,7-difluoro-2-(2,3-difluoro-4-heptylphenyl)benzo[b]furan**

The title compound was prepared and purified in a similar manner to that described in Example 24(1) using the quantities stated.

2,3-Difluoro-1-iodo-4-heptylbenzene (Example 52 (4)) (2.3 g, 6.7 mmol), 5-Bromo-6,7-difluorobenzo[b]furan-2-boronic acid (Example 58(6)) (1.6 g, 5.6 mmol), sodium carbonate (1.8 g, 17.0 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol)

A white, crystalline solid was obtained.

Yield 0.6 g (24%), mp 62-65 °C

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.69 (1H, ddd), 7.60 (1H, dd), 7.18 (1H, dd), 7.12 (1H, ddd), 2.72 (2H, dt), 1.65 (2H, qui), 1.31 (8H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2932, 2856, 1605, 1476, 1210, 1031, 932, 869, 731, 606

MS *m/z* 444, 442(M<sup>+</sup>)(100%), 357, 277, 249, 230

## **Step 2**

### **10 Preparation of 6,7-Difluoro-2-(2,3-difluoro-4-heptylphenyl)-5-(4-heptylphenyl)benzo[b]furan (Compound 76 in Table 1)**

The title compound was prepared in a similar manner to that described in Example 24(1) using the quantities stated.

The product of step 1 (0.6 g, 1.2 mmol), 4-heptylbenzeneboronic acid (0.3 g, 1.5 mmol), sodium carbonate (0.3 g, 3.0 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol)

The product was purified by flash chromatography [silica gel / petroleum fraction (bp 40-60 °C)], followed by recrystallisation (ethanol).

Colourless, plate-like crystals were obtained.

Yield 0.1 g (17%). Purity (hplc) >99%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.72 (1H, ddd), 7.47 (2H, dd), 7.40 (1H, dd), 7.30 (2H, d), 7.25 (1H, dd), 7.12 (1H, ddd), 2.72 (2H, t), 2.67 (2H, t), 1.39-1.62 (4H, m), 1.37-1.28 (16H, m), 0.90 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2928, 2857, 1616, 1475, 1164, 1093, 932, 879, 809, 719

MS *m/z* 538(M<sup>+</sup>)(100%), 467, 453, 368, 184

**Example 60****Preparation of Compound 77 in Table 1****Step 1****Preparation of 5-(2,3-Difluoro-4-heptyl)-6,7-difluorobenzo[b]furan**

- 5           The title compound was prepared and purified in a similar manner to that described in Example 24(1) using the quantities stated.
- 5-Bromo-6,7-difluorobenzo[b]furan (1.1 g, 4.7 mmol), 1-heptyl-2,3-difluorobenzene-4-boronic acid (1.4 g, 5.6 mmol), sodium carbonate (1.3 g, 12.0 mmol), tetrakis(triphenylphosphine)palladium(0) (0.2 g, 0.2 mmol)
- 10   After refluxing (1 day) tlc and glc analysis revealed some starting material still remained, so compound 161 (0.6 g, 2.3 mmol) and catalyst (0.1 g, 0.1 mmol) were added.

A white, crystalline solid was obtained.

Yield 0.8 g (47%), mp 57-59.5 °C

- 15   <sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ           7.75 (1H, d), 7.35 (1H, ddd), 7.08 (2H, m), 6.87 (1H, dd), 2.73 (2H, dt), 1.66 (2H, qui), 1.34 (8H, m), 0.90 (3H, t)

IR (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2921, 2859, 1618, 1512, 1121, 1046, 963,  
807, 738, 671

- 20   MS *m/z*                   364(M<sup>+</sup>), 335, 279(100%), 250, 201

**Step 2****Preparation of 5-(2,3-Difluoro-4-heptyl)-6,7-difluorobenzo[b]furan-2-boronic acid**

- 25           The title compound was prepared and purified in a similar manner to that described for the preparation of 4'-pentylphenylboronic acid (Example 20(2)) using the quantities stated.

Product of step 1 (0.7 g, 1.9 mmol), n-butyllithium (2.5M in hexanes, 0.9 ml, 2.3 mmol), trimethyl borate (0.4 g, 3.8 mmol).

A white solid was obtained.

Yield 0.8 g (quant).

- 30   MS *m/z*                   364(M<sup>+</sup>-B(OH)<sub>2</sub>), 292, 279(100%), 250, 121

**Step 3****Preparation of 2-(4-Heptylphenyl)-5-(2,3-difluoro-4-heptyl)-6,7-difluorobenzo[b]furan (Compound 77)**

The title compound was prepared and purified in a similar manner to that described in Example 24(1) using the quantities stated.

1-Heptyl-4-iodobenzene (0.7 g, 2.4 mmol), the product of step 2 (0.8 g, 2.0 mmol), sodium carbonate (0.6 g, 5.7 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol)

Final purification was by preparative hplc (acetonitrile/chloroform 4:1).

A white, crystalline solid was obtained.

Yield 0.1 g (5%). Purity (hplc) >99.9%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 7.80 (2H, d), 7.32 (1H, m), 7.31 (2H, d), 7.13-7.07 (1H, m), 7.12-7.06 (1H, m), 7.04 (1H, d), 2.73 (2H, dt), 2.67 (2H, t), 1.69 (2H, qui), 1.67 (2H, qui), 1.38-1.26 (16H, m), 0.90 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2929, 2859, 1618, 1279, 1053, 969, 908, 835, 811

MS m/z 538(M<sup>+</sup>)(100%), 453, 416, 368, 290

**Example 61****Preparation of Compound 78 in Table 1****Step 1****Preparation of 2,3-Difluoro-4-heptylphenol**

The title compound was prepared and purified in a similar manner to that described for in Example 58(2) using the quantities stated.

Hydrogen peroxide (100 vol, 27.0 ml, 238.0 mmol), 1-heptyl-2,3-difluorobenzene-4-boronic acid (10.0 g, 39.0 mmol).

A colourless liquid was obtained.

Yield 5.9 g (66%), bp 205 °C at 20 mmHg.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 6.82 (1H, ddd), 6.69 (1H, ddd), 5.25 (1H, s, br), 2.58 (2H, dt), 1.56 (2H, t), 1.31 (8H, m), 0.88 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  3390, 2935, 2863, 1643, 1609, 1517, 1183, 1024, 961,  
809, 676  
**MS**  $m/z$  228( $M^+$ ), 169, 156, 143(100%), 95

**Step 2****5 Preparation of 2-(2,3-Difluoro-4-heptylphenoxy)acetaldehyde dimethyl acetal**

The title compound was prepared and purified in a similar manner to that described for the preparation of 2-(4-pentylphenoxy)acetaldehyde dimethyl acetal in Example 25(1) using the quantities stated.

2,3-Difluoro-4-heptylphenol (5.8 g, 25.0 mmol), bromoacetaldehyde dimethyl acetal  
10 (5.1 g, 30.0 mmol), potassium carbonate (6.9 g, 50.0 mmol), potassium iodide (0.2 g, 1.3 mmol).

A colourless oil was obtained, which solidified on cooling to a waxy solid.

Yield 5.4 g (68%) bp 170 °C at 0.05 mmHg.

**$^1\text{H}$  NMR**  $\text{CDCl}_3/\delta$  6.81 (1H, ddd), 6.67 (1H, ddd), 4.72 (1H, t), 4.05 (2H,  
15 d), 3.47 (6H, s), 2.57 (2H, dt), 1.57 (2H, m), 1.29 (8H, m), 0.88 (3H, t)

**IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2936, 2863, 1640, 1513, 1176, 1151, 1115,  
1095

**MS**  $m/z$  316( $M^+$ ), 284, 253, 126, 75(100%)

**20 Step 3****Preparation of 6,7-Difluoro-5-heptylbenzo[b]furan**

The title compound was prepared and purified in a similar manner to that described for the preparation of 5-bromobenzo[b]furan (Example 9(2)) using the quantities stated.

25 The product of step 2 (5.4 g, 17.0 mmol), polyphosphoric acid (7.3 g).

A pale yellow liquid was obtained.

Yield 0.5 g (12%) bp 135 °C at 0.1 mmHg.

**$^1\text{H}$  NMR**  $\text{CD}_2\text{Cl}_2/\delta$  7.65 (1H, d), 7.16 (1H, m), 6.76 (1H, dd), 2.72 (2H, dt),  
1.63 (2H, qui), 1.31 (8H, m), 0.88 (3H, t)

30 **IR** (KBr)  $\nu_{\max}/\text{cm}^{-1}$  2933, 2867, 1616, 1131, 1077, 926, 871,  
763, 733, 551

MS *m/z* 252( $M^+$ ), 209, 167(100%), 153, 118

**Step 4**

**Preparation of 6,7-Difluoro-5-heptylbenzo[b]furan-2-boronic acid**

The title compound was prepared and purified in a similar manner to that described in Example 20(2) using the quantities stated.  
The product of step 3 (0.5 g, 1.8 mmol), *n*-butyllithium (2.5M in hexanes, 0.8 ml, 2.0 mmol), trimethyl borate (0.4 g, 3.6 mmol).  
An orange solid was obtained.

Yield 0.3 g (66%)

10 MS *m/z* 252( $M^+$ ), 180, 167(100%), 119, 57

**Step 5**

**Preparation of 4-Bromo-3-fluoro-4'-pentylbiphenyl**

The title compound was prepared and purified in a similar manner to that described in Example 24(1) using the quantities stated.  
15 1-Bromo-2-fluoro-4-iodobenzene (6.4 g, 21.0 mmol), 4-pentylbenzeneboronic acid (Example 3(2)) (4.5 g, 23.0 mmol), sodium carbonate (5.6 g, 53.0 mmol), tetrakis(triphenylphosphine)palladium(0) (1.2 g, 1.0 mmol)  
The product was further purified by distillation.  
A pale-yellow liquid was obtained.

20 Yield 1.7 g (25%) (a quantity was lost through spillage) bp 190 °C at 0.04 mmHg.

$^1\text{H}$  NMR  $\text{CD}_2\text{Cl}_2/\delta$  7.60 (1H, dd), 7.49 (2H, d), 7.37 (1H, dd), 7.29 (1H, dd),  
7.28 (2H, d), 2.65 (2H, t), 1.64 (2H, qui), 1.35 (4H, m),  
0.91 (3H, t)

25 IR (KBr)  $\nu_{\text{max}}/\text{cm}^{-1}$  2933, 2861, 1560, 1195, 1057, 875, 805,  
547

MS *m/z* 322,320( $M^+$ ), 263, 250, 183(100%), 170

**Step 6**

**Preparation of 2-(2-Fluoro-4'-pentylbiphenyl)-6,7-difluoro-5-heptylbenzo[b]furan (Compound 78)**

30 The title compound was prepared and purified in a similar manner to that described for in Example 24(1) using the quantities stated.



Product of step 5 (03.5 g, 1.4 mmol), product of step 4 (0.3 g, 1.2 mmol), sodium carbonate (0.4 g, 3.5 mmol), tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol)

Final purification was by preparative hplc (acetonitrile/chloroform 4:1).

5 A white solid was obtained.

Yield 0.04 g (7%). Purity (hplc) 99.2%.

<sup>1</sup>H NMR CD<sub>2</sub>Cl<sub>2</sub>/δ 8.07 (1H, dd), 7.58 (2H, d), 7.55 (1H, dd), 7.45 (1H, dd),  
7.30 (2H, d), 7.21-7.19 (1H, m), 7.19-7.17 (1H, m), 2.75  
(2H, dt), 2.66 (2H, t), 1.68-1.64 (4H, m), 1.37-1.26 (12H,  
10 m), 0.91 (3H, t), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2925, 2855, 1614, 1556, 1110, 1062, 915,  
866, 800

MS *m/z* 492(M<sup>+</sup>)(100%), 435, 407, 350, 175

### **Example 62**

#### 15 **Preparation of Compound 1 in Table 1**

##### **Step 1**

##### **Preparation of 1-Bromo-4-octyloxybenzene**

A mixture of *p*-bromophenol (40.0 g, 231 mmol), *n*-octyl bromide (50.2 g, 260 mmol), potassium carbonate (35.9 g, 260 mmol) and potassium iodide (2.2 g, 13  
20 mmol)

in butanone (500 ml) was refluxed under nitrogen (48 h) and the reaction monitored by glc analysis. The mixture was filtered, and the solid washed with ether (2 x 300 ml).

The filtrate was washed with sodium hydroxide (10%), followed by brine. The solvent was removed *in vacuo*, and the product purified by distillation.

25 A colourless liquid was obtained.

Yield 61.0 g (93%) bp 145 °C at 0.02 mmHg (lit.<sup>3</sup> 125°C).

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.35 (2H, d), 6.76 (2H, d), 3.90 (2H, t), 1.76 (2H, qui),  
1.35 (10H, m), 0.89 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2900, 1580, 1475, 1240, 1170, 1070, 820,

30 640, 500

MS *m/z* 286,284(M<sup>+</sup>), 171(100%), 157, 143, 93

**Step 2****Preparation of 2-methyl-4-(4-octyloxyphenyl) but-3-yn-2-ol**

A mixture of compound the product of step 1 (61.0g, 214 mmol), tetrakis(triphenylphosphine)palladium(0) (2.4 g, 2.1 mmol), cuprous iodide (0.4 g, 2.1 mmol) and dry diisopropylamine (400 ml) was stirred under nitrogen (10 min). 2-Methyl-but-3-yn-2-ol (45.0 g, 535 mmol) in dry diisopropylamine (90 ml) was added dropwise, and the mixture was refluxed (4 h); the reaction progress was monitored by tlc analysis. When cool, water was added, and the mixture was filtered through a pad of 'Hyflo Supercel', washing the pad with ether. The separated aqueous layer was washed with ether (2 x 300 ml), and the combined organic layers washed with brine and dried (MgSO<sub>4</sub>). After removal of the solvent *in vacuo*, the product was purified by flash chromatography [silica gel, petroleum fraction (bp 40-60 °C) (unreacted starting material), and DCM (product)].

A heavy brown oil was obtained

Yield 33.2 g (54%).

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.33 (2H, d), 6.81 (2H, d), 3.93 (2H, t),  
1.76 (2H, qui), 1.60 (6H, s), 1.28 (12H, m), 0.88 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3440, 2880, 1600, 1505, 1465, 1370, 1245,  
960, 835

MS m/z 288,286(M<sup>+</sup>), 273, 175, 159, 43(100%)

**Step 3****Preparation of 4-Octyloxyphenylacetylene**

The product of step 2 (33.0 g, 115 mmol) and potassium hydroxide (7.1 g, 126 mmol) in toluene (250 ml), were refluxed with stirring under nitrogen (3.5 h), using a Dean and Stark apparatus. Tlc analysis indicated a complete reaction. The cooled reaction mixture was poured into water (150 ml) and the layers were separated. The aqueous phase was neutralised with hydrochloric acid (0.02 M) to pH 7, and washed with ether (3 x 100 ml). The combined organic layers were washed with brine and dried (MgSO<sub>4</sub>). After removal of the solvent *in vacuo*, the residue was flash chromatographed [silica gel / petroleum fraction (bp 40-60 °C), DCM 1:1]. The product was then distilled *in vacuo*.  
A pale-yellow liquid was obtained.

Yield 6.4 g (68%) bp 122 °C at 2.7 mmHg

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 7.42 (2H, d), 6.82 (2H, d), 3.94 (2H, t), 3.00 (1H, s), 1.77 (2H, qui), 1.35 (10H, m), 0.88 (3, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3310, 3290, 2920, 2850, 2110, 1600, 1500,

5 830

MS *m/z* 230(M<sup>+</sup>), 187, 145, 118(100%), 101

#### Step 4

##### Preparation of 4,6-Diiodoresorcinol

To resorcinol (5.0 g, 45 mmol) in hydrochloric acid (conc.) / water 14:11 v/v  
10 (185 ml), iodine monochloride (14.6 g, 90 mmol) was added with stirring under nitrogen. Stirring was continued (15 min), followed by addition of solid sodium sulphite until the iodine colouration was removed. The reaction mixture was filtered and the solid washed with cold water. The solid was then dried *in vacuo* (KOH) and recrystallized (CCl<sub>4</sub>).

15 Colourless needles were obtained.

Yield 8.6 g (53%) mp 139-145 °C (lit.<sup>4</sup> 145°C).

<sup>1</sup>H NMR DMSO-d<sub>6</sub>/δ 9.55 (2H, s), 7.57 (1H, s), 6.53 (1H, s)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 3455, 1565, 1285, 1150, 1030, 875, 630,  
460

20 MS *m/z* 362(M<sup>+</sup>), 235, 108, 79, 50(100%)

#### Step 5

##### Preparation of 4,6-Diiodoresorcinol dibenzoate ester

To a stirred mixture of compound the product of step 4 (15.0 g, 42 mmol) and benzoyl chloride (12.8 g, 91 mmol) in dry DCM (150 ml), dry triethylamine (9.2 g, 91  
25 mmol) was added dropwise with exclusion of moisture, and the mixture was then refluxed (2 h). When cool, the mixture was poured into water and washed with DCM (2 x 200 ml). The combined organic phases were washed with hydrochloric acid (0.1M) and water, and dried (MgSO<sub>4</sub>). The solvent was removed *in vacuo* and the residue recrystallized (toluene).

30 White, fibrous crystals were obtained.

Yield 20.6 g (86%), mp 185-7 °C (lit.<sup>4</sup> 195-200°C (decomp.)).

<sup>1</sup>H NMR CDCl<sub>3</sub>/δ 8.36 (1H, s), 8.26 (4H, d), 7.68 (2H, t),  
7.54 (4H, t), 7.31 (1H, s)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 1745, 1235, 1150, 1050, 700

MS m/z 570(M<sup>+</sup>), 443, 127(100%), 105, 77

5 **Step 6**

**Preparation of 2-(4-Octyloxyphenyl)-5-(4-octyloxyphenylethynyl)benzo[b]furan-6-benzoate ester (Compound 1)**

The product of step 3 (0.7g, 3 mmol) was placed in a three-necked flask fitted with septum, condenser, thermometer and addition funnel. The apparatus was heated, evacuated, and flushed with nitrogen. Dry THF (10 ml), was added and the system  
10 degassed at -40 °C. The flask was flushed with nitrogen and n-butyllithium (1.4 ml, 3.5 mmol, 2.5M in hexanes) was added dropwise with stirring, maintaining the temperature below 0 °C. The mixture was stirred at this temperature (15 min), the system was cooled (-40 °C) and anhydrous zinc chloride (0.5 g, 3.5 mmol) in dry THF  
15 (20 ml) was added dropwise with stirring. The mixture was allowed to return to room temperature whilst stirring. The product of step 5 (0.7 g, 1.2 mmol) and tetrakis(triphenylphosphine)palladium(0) (0.1 g, 0.1 mmol) were added and the mixture refluxed with stirring under nitrogen. When tlc analysis indicated no further reaction (3 days), the mixture was allowed to cool. The solvent was removed *in vacuo*  
20 and the residue triturated with ether, whence a white solid precipitated. The solid was then re-triturated with petroleum fraction (bp 40-60 °C) from solution in methanol, and finally recrystallized (ethanol).

Pale yellow crystals were obtained.

Yield 0.1 g (14%). Purity (hplc) >98%.

25 <sup>1</sup>H NMR CDCl<sub>3</sub>/δ 8.34 (2H, d), 7.77 (2H, d), 7.74 (1H, s), 7.67 (1H, t), 7.53 (2H, t), 7.47 (1H, s), 7.09 (2H,d), 6.97 (2H, d), 6.86 (1H, d), 6.69 (2H, d), 4.20 (2H, t) 3.90 (2H, t), 1.78 (4H, m), 1.30 (20H, m), 0.89 (3H, t), 0.88 (3H, t)

IR (KBr) ν<sub>max</sub>/cm<sup>-1</sup> 2920, 2850, 1735, 1500, 830

30 MS m/z 671(M<sup>+</sup>), 566, 446, 341, 105(100%)

**Example 63****Liquid Crystal Properties**

The liquid crystal properties of the compounds of the invention were tested using conventional methods. Examples of transitions are provided above in the Examples.

- 5 However, the results are summarised in Table 3.

Table 3

Compound	Transition Temp °C	Enthalpy/Jg <sup>-1</sup>
1	K 87.1 N 150.5 Iso	
2	K 39 [36.8SmA] Iso	
3	K 31.1 N 60.5 Iso	67.3 1.8
4	K 132 SmA 184.1 Iso	
5	K 76 SmA 140.9 N 144.4 Iso	
6	K 118 SmA 151.9 Iso	
7	K 103 SmA 158 N 178.4 Iso	
8	K 95.4 SmA 158 N 170 Iso	
9	K 78.5 SmA 146.2 N Iso	
10	K 98.7 SmA 152.2 Iso	
11	K 75.8 SmA 123.2 (TGBA*) N* 133.2 (BPI-III) Iso	
12	K 103 SmA 119.7 Iso	68.8 2.3
13	K 101 SmI/F 104.5 SmA 114.9 Iso	
14	K 86.5 N 87.5 Iso	69.1 -1.1 (cooling)
15	K 129.5 SmA 180 N 186 Iso	
16	K 62 SmA 87 N 97 Iso	83.4 0.3 1.3
17	K 40 SmA 44.5 N 48.5 Iso	
18	K 104.5 SmA 183.5 N 194 Iso	
19	K 104 SmA 182.5 N 185 Iso	
20	K 120 SmA 193 N 214.5 Iso	
21	K 106.5 SmA 188.5 N 203.5 Iso	
22	K 110.5 SmA 161.5 N* 172.5 BPI 173.5 Iso	
23	K 14 SmA 247 Iso	

Compound	Transition Temp °C	Enthalpy/Jg <sup>-1</sup>
24	K [51 SmA] 76 Iso	
25	K 58 [48.9 N] Iso	97.1 –0.6 (cooling)
26	K 51.1 N 56.4 Iso	97.7 0.6
27	K 99.7 [86.5 N] Iso	93.9 –1.2 (cooling)
28	K 147.3 [134 B] N 255.6 Iso	66.1 –0.4 (cooling) 1.6
29	K 187.1 N 284.2 Iso	35.5 2.2
30	K 134 SmA 186.8 N 191.4 Iso	
31	K 90.9 SmC 97.1 SmA 134 N 143.1 Iso	
32	K 70.1 SmC 100.7 SmA 109.1 N 142.6 Iso	
33	K 145.9 SmA 184.5 Iso	
34	K 28.1 SmA 49.6 N 60 Iso	49.5 0.2 1.7
35	K 139 N 252.6 Iso	79.0 1.2
36	K 28.2 SmA 34.3 N 48.8 Iso	58.9 0.2 0.7
37	K 107.9 N 148.4 Iso	
38	K 74 N 119.7 Iso	
39	K 89.8 N 94.6 Iso	
40	K 24.5 N 45.2 Iso	9.3 0.6
41	K 77.6 (N 58.5) Iso.	91.6 –1.6 (cooling)
42	K 98.0 Iso	
43	K 200.3 SmC 255.8 Iso	
45	K 151.5 SmA 152.0 Iso	
46	K 172 SmC 193.2 N 253.7 Iso	
47	K 225 N 235 Iso	
48	K 43.0 (30.9N) Iso	
50	K 133.8 N 230.5 Iso	51.3 0.7
51	K150.8 B167.0 N 280.3 Iso	31.8 30.1 1.9
52	K 94/8 n 236.7 Iso	81.4 1.5
53	K 183 N 299 Iso	

Compound	Transition Temp °C	Enthalpy/Jg <sup>-1</sup>
54	K 86.5 N 87.5 Iso	
55	K 113.0 n 240.7 Iso	64.5 2.1
57	K 96.4 SmA 144.3 N 145.8 Iso	
58	K 63.0 SmA 134.3 Iso	
59	K 81.7 (71.7 N) Iso	
62	K 76.0 SmA 140.9 N 144.4 Iso.	
64	K 103.0 SmA 158.0 N 178.4 Iso.	
65	K 95.4 SmA 158.0 N 170.0 Iso.	
66	K 78.5 SmA 146.2 N 155.0 Iso.	
67	K 75.8 SmA 122.5 TGBA* 123.2 N* 130.8 BPI-III 133.2 Iso.	
68	K 9.7 Iso (Recryst. 0.1 °C).	
69	K 76.0 (51.0 SmA) Iso.	
70	K 104.5 SmA 183.5 N 194.0 Iso.	
71	K 90.0 SmA 100.5 Iso.	
72	K 104.0 SmA 182.5 N 185.0 Iso.	
73	K 120.0 SmA 193.0 N 214.5 Iso.	
74	K 106.5 SmA 188.5 N 203.5 Iso.	
76	K 110.5 SmA 161.5 N* 172.5 BPI 173.5 Iso.	
77	K 14.0 SmA 27.0 Iso.	
78	K 132.0 SmA 184.1 Iso.	
79	K 129.5 SmA 180.0 N 186.0 Iso.	
80	K 118.0 SmA 151.9 Iso.	
81	K 96.4 SmA 144.3 N 145.8 Iso.	
82	K 70.1 SmC 100.7 SmA 109.1 N 142.6 Iso.	
83	K 40.0 SmA 44.5 N 48.5 Iso.	
84	K 77.6 SmA 103.4 Iso.	
85	K 134.0 SmA 186.8 N 191.4 Iso.	

Compound	Transition Temp °C	Enthalpy/Jg <sup>-1</sup>
86	K 90.9 SmC 97.1 SmA 134.0 N 143.1 Iso.	
87	K 107.9 SmA 148.4 Iso.	
88	K 74.0 N 119.7 Iso.	
89	K 89.8 N 94.6 Iso.	
90	K 81.7 (N 71.7) Iso.	
91	K 63.0 SmA 134.3 Iso.	
92	K 87.1 N 150.0 Iso.	
102	K 93.2 Iso	56.5

**Example 64****Liquid crystal properties of mixtures including Compounds of the Invention**

A number of mixtures were prepared by adding a given percentage of the compounds of the invention to general host mixture comprising ethyl linked phenyl cyclohexanes.

5 The properties of the mixtures were analysed using conventional methods and the results are set out in the following Tables 4-7.

Table 4

10

**Phase behaviour, mixture composition and structure**

Mixture number	Compd No.	%	Clearing point of mixture (°C)	Transition Temp.
1	28	15.5	76	K-134-B-147.3-N-255.6-Iso
2	26	22	55.4	K-51.1-N-56.4-Iso
3	17	15	52.7	K-40-SmA-44.5-N-48.5-Iso
4	19	11.5	66.8	K-104-SmA-182.5-N-185-Iso
5	18	10	65.7	K-104.5-SmA-183.5-N-194-Iso
6	37	10 5	61.8 57.7	K-107.9-N-148.4-Iso



Mixture number	Compd No.	%	Clearing point of mixture (°C)	Transition Temp.
7	38	10	59	K-74-N-119.7-Iso
8	82	10	62.6	K-70.1-SmC-100.7-SmA-109.1-N-142.6-Iso
9	31	10	61.6	K-90.9-SmC-97.1-SmA-134-N-143.1-Iso
10	35	10	70.8	K-139-N-252.6-Iso
11	3	10	57.2	K-31.1-N-60.5-Iso
12	21	10	68.5	K-106.5-SmA-188.5-N-203.5-Iso
13	22	10	63.7	K-110.5-SmA-188.5-N-203.5-Iso
14	27	10	57.7	K-(86.5)-N-99.7-Iso
15	29	10	63.4	K-187.1-N-284.2-Iso
16	4	10	67.0	K-132-SmA-184.1-Iso

This data provides some indications regarding the structural effects on the properties. For example, the influence of fluorine substituents can be assessed by comparison of the properties of mixtures 7 and 8 and 9 and 16. When fluorines are present on the remote ring (mixtures 8 and 9 including compounds 82 and 31 respectively), smectic phases are observed, but when they are on the benzofuran central ring (as in mixture 7 including compound 38), only a nematic phase is observed. The transition temperatures are significantly lower in the fluorinated compounds as compared to the corresponding non-fluorinated compound.

10

Table 5

Permittivities (of mixtures at 20°C – not extrapolated)

Mixture	$\epsilon_{\perp}$	$\epsilon_{\parallel}$	$\Delta\epsilon$
1	4.42	12.32	7.90
2	4.80	12.67	7.87
3	4.496	9.963	5.47
4	4.498	9.836	5.34
5	4.50	9.96	5.46

Mixture	$\epsilon_{\perp}$	$E_{\parallel}$	$\Delta\epsilon$
7	5.37	12.04	6.67
8	4.93	12.06	7.13
9	5.23	12.13	6.90
10	4.95	13.56	8.61
14	5.20	13.87	8.67
15	5.10	13.31	8.21
16	4.78	11.83	7.05
Mixture*	5.13	12.95	7.82

It would appear, from a comparison of mixtures 1, 2 and 14, that  $\epsilon_{\perp}$  is greater when the nitrile is a substituent on the phenyl rather than the furyl ring of the benzofuran (i.e. where  $R^1$  is cyano in preference to  $R^3$ ). This also appears to lead to an increase in  $\Delta\epsilon$  (from 7.8 to 8.7)

Table 6

Birefringence and refractive indices (of mixtures, not extrapolated)

Mixture	Temperature (°C)	$n_o$	$N_e$	$N_{bar}$	$\Delta n$
1	40	1.4898	1.6084	1.5491	0.118
	25	1.4924	1.9199	1.5562	0.128
2	40	1.4938	1.5954	1.5446	0.102
	25	1.4950	1.61193	1.5534	0.111
4	40	1.4852	1.5853	1.5353	0.100
	25	1.4882	1.5977	1.5429	0.1095
5	40	1.4854	1.5843	1.5348	0.099
	25	1.488	1.606	1.472	0.118
6 (5%)	40	1.4838	1.5733	1.5285	0.089
	25	1.4859	1.5867	1.5363	0.1008
7	40	1.4858	1.5799	1.5329	0.094
	25	1.4876	1.5935	1.5406	0.106
8	40	1.4851	1.5838	1.5344	0.099
	25	1.4879	1.5968	1.5424	0.109

Mixture	Temperature (°C)	$n_o$	$N_e$	$N_{bar}$	$\Delta n$
9	40	1.4853	1.5825	1.5339	0.097
	25	1.4879	1.5958	1.5418	0.108
10	40	1.4883	1.6032	1.5457	0.115
	25	1.4913	1.6157	1.5535	0.124
11	40	1.4874	1.5790	1.5332	0.092
	25	1.4892	1.5935	1.5413	0.104
12	40	1.4841	1.5714	1.5296	0.091
	25	1.4866	1.5881	1.5374	0.102
14	40	1.4881	1.5860	1.5371	0.098
	25	1.4899	1.6009	1.5454	0.111
15	40	1.4854	1.5852	1.5353	0.095
	25	1.4879	1.5980	1.5430	0.110
16	40	1.486	1.588	1.537	0.102
	25	1.488	1.600	1.545	0.112
Mixture*	40	1.4834	1.5658	1.5109	0.0825
	25	1.4854	1.5796	1.5168	0.0943

\* Base mixture of ethyl linked phenyl cyclohexanes without a compound of the invention.

Properties of ester containing compounds can be compared by comparing the results for mixtures 4, 5 and 12 and below.

Properties of three ring systems can be assessed relative to each other by comparing the results for example obtained with mixtures 1, 10 and 15. This indicates that the relative position of the benzofuran ring to the phenyl rings in the system has quite a large effect on the dielectric anisotropy.

A comparison of the results for mixtures 1, 2, 11 and 14 indicates that the position of a cyano group on different rings of the benzofuran ring does not appreciably affect the birefringence.

However a comparison of three ring systems 1, 10 and 15 indicates that the birefringence of the mixture is lower when the benzofuran moiety is in the middle of the phenyl rings and remote from a cyano substituent.

The effects of other groups such as pyrimidines, triple bonds and chiral moities may be assessed for example by the results obtained with mixtures 3, 6 and 13.

Compound no. 37 in mixture 6 showed a tendency to precipitate out of solution and therefore, a 5% mixture was used in some of the tests. Compound 17 was less stable than some other compounds.

Each mixture was filled into a 6µm TN cell with rubbed polyimide alignment layers and the optical switching time at 25°C, 40°C and (T<sub>N-I</sub>-30) °C with the application of 5V pk-pk 1 KHz square wavemeasured. The results are shown in Table 7, along with measurement of the mixture of ethyl linked phenyl cyclohexanes in the absence of compounds of the invention in a cell from the same batch.

Table 7

Mixture	Temperature °C	$\tau$ off (ms)	$\tau$ on (ms)
1	40	12.6	1.64
	<b>47.8</b>	<b>11.2</b>	<b>1.24</b>
	25	20.2	2.96
2	40	16.9	1.25
	<b>25.4</b>	<b>21.4</b>	<b>2.20</b>
	25	17.2	2.22
4	40	15.5	2.02
	<b>37.4</b>	<b>15.8</b>	<b>2.18</b>
	25	23.2	3.52
5	40	14.7	1.50
	<b>36.3</b>	<b>16.0</b>	<b>1.74</b>
	25	23.2	2.84
6	40	18.1	2.16
	<b>32.2</b>	<b>20.3</b>	<b>2.8</b>
	25	24.8	3.64
7	40	14.4	1.50
	<b>29.2</b>	<b>18.6</b>	<b>2.32</b>
	25	22.8	2.94

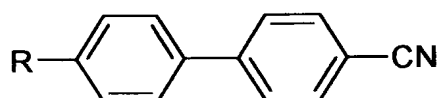
Mixture	Temperature °C	$\tau$ off (ms)	$\tau$ on (ms)
8	40	14.8	1.74
	<b>32.8</b>	<b>17.1</b>	<b>2.28</b>
	25	20.6	3.12
9	40	17.7	1.96
	<b>31.8</b>	<b>20.1</b>	<b>2.60</b>
	25	23.8	3.42
10	40	13.0	1.71
	<b>41.5</b>	<b>12.4</b>	<b>1.61</b>
	25	19.4	3.08
11	40	17.44	1.44
	<b>27.5</b>	<b>22.04</b>	<b>2.39</b>
	25	24.60	2.80
12	40	17.00	1.84
	<b>40.2</b>	<b>17.56</b>	<b>1.83</b>
	25	23.80	3.33
14	40	14.46	1.42
	<b>27.7</b>	<b>18.20</b>	<b>2.33</b>
	25	19.20	2.66
15	40	14.46	1.53
	<b>34.1</b>	<b>15.36</b>	<b>1.90</b>
	25	20.08	2.77
16	40	15.16	2.07
	<b>37</b>	<b>15.8</b>	<b>2.33</b>
	25	21.2	3.68

The switching speeds indicate that the compounds of the invention have a low switching viscosity.

Looking at the reduced temperature ( $T_{NI}-30$ ) °C switching times (shown in bold in Table 7), these are generally significantly faster than in the pure compound. This appeared to be the case even when terphenyls and negative materials are added.

**Example 65****Comparison of Mixture of Compounds of the Invention with Cyanobiphenyl compounds**

A comparison of the eutectic mixture (as calculated using the Schroeder van Laar equation) of the corresponding cyanobiphenyls of formula A



A

where R is propyl- (C3), pentyl- (C5) and heptyl (C7) and the equivalent eutectic mixture of the propyl- pentyl and heptyl phenyl benzofurans was made and the results are as shown in Tables 8-10.

Table 8

Phase behaviour and composition of mixtures

Comparative Cyanobiphenyl mixture	Mixture of Compounds of Invention
C3 - 10.5%	Compound No. 25 (C3) 31.72%
C5 - 55.8%	Compound No. 26 (C5) 19.4%
C7 - 33.7%	Compound No. 3 (C7) 48.88%
Iso - 35.5 N- <-40 - K °C	Iso - 52.8 N- <-40 - K °C

The phase behaviour and composition of the mixtures is given in Table 8. The benzofuran mixture has a higher clearing point than the cyanobiphenyl mixture by over 15°. Neither mixture recrystallised when held at -40 °C for 40 minutes, although it is likely that both would recrystallise at this temperature if held for a sufficiently long time.

Table 9

## Birefringence and refractive indices

Comparative mixture (see Table 8)				Invention mixture (see Table 8)		
T °C	n <sub>e</sub>	n <sub>o</sub>	Δn	n <sub>e</sub>	n <sub>o</sub>	Δn
40	-	-	-	1.719	1.543	0.176
30	1.698	1.535	0.163	1.738	1.541	0.198
25	1.712	1.531	0.181	1.747	1.541	0.206
20	1.723	1.530	0.193	1.754	1.541	0.213

These results show that the birefringence is higher for the compounds of the invention,  
 5 as is the dielectric anisotropy.

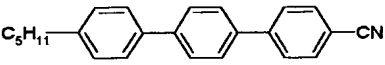
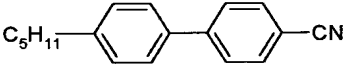
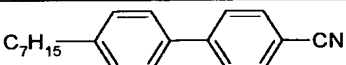
Table 10

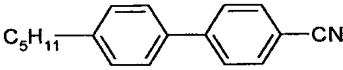
## Dielectric permittivities

Comparative mixture (Table 8)				Invention mixture (Table 8)		
T °C	ε <sub>⊥</sub>	ε <sub>  </sub>	Δε	ε <sub>⊥</sub>	ε <sub>  </sub>	Δε
25	6.28	18.39	12.11	5.919	20.045	15.44

The liquid crystal properties of mixtures including compounds of the invention were  
 10 compared with similar mixtures using the corresponding compounds where the  
 benzofuran ring had been substituted with a phenyl ring. The results are shown in  
 Table 11

Table 11

Comp. No.	% in mix	Phase behaviour of mixture including compound	Structure of Comparative compound	Phase behaviour of comparative mix
28	15.5	K-134-B-147.3-N-255.6-Iso		K-130-N-239-Iso
26	22	K-51.1-N-56.4-Iso		K-22.5-N-35-Iso
14	10	K-31.1-N-60.5-Iso		K-28.5-N-42-Iso

Comp. No.	% in mix	Phase behaviour of mixture including compound	Structure of Comparative compound	Phase behaviour of comparative mix
27	10	K-(86.5-N)-99.7-Iso		K-22.5-N-35-Iso

These results indicate that, generally, the compounds of the invention have a wider nematic phase range than the equivalent biphenyl compounds. (The range is slightly reduced in the case of terphenyl equivalents).

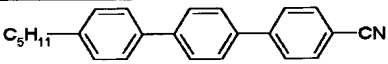
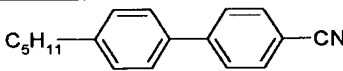
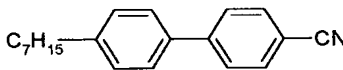
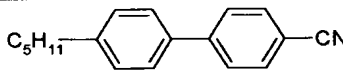
### 5 **Example 66**

#### **Liquid Crystal Properties of Mixtures of Fluoro vs Non-Fluoro Compounds of the Invention**

The phase behaviour and structure of mixtures of compounds of the invention including difluoro compounds some of the mixtures defined in Table 11 were

10 measured

Table 11

Comp. No.	% in mix	Phase behaviour of mixture including compound	Structure of Comparative compound	Phase behaviour of comparative mix
28	15.5	K-134-B-147.3-N-255.6-Iso		K-130-N-239-Iso
26	22	K-51.1-N-56.4-Iso		K-22.5-N-35-Iso
14	10	K-31.1-N-60.5-Iso		K-28.5-N-42-Iso
27	10	K-(86.5-N)-99.7-Iso		K-22.5-N-35-Iso

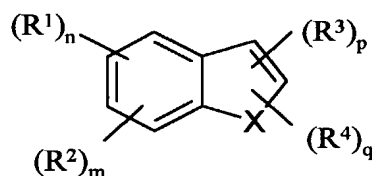
Compounds of the invention have in some cases wider nematic phase ranges than the equivalent biphenyl compounds.



## Claims

1. A liquid crystal compound of general formula (I)

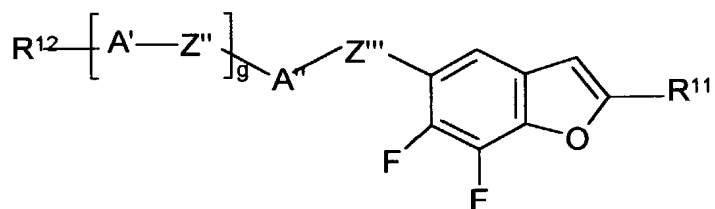
5



(I)

where X is O, S or Se,

- 10 each  $R^1$  and  $R^3$  are independently selected from cyano, halo, optionally substituted hydrocarbyl, optionally substituted alkoxy, optionally substituted heterocyclyl, a group  $R^{13}C(O)O-$  where  $R^{13}$  is optionally substituted hydrocarbyl or carboxy or a hydrocarbyl ester or amide thereof, provided that at least one or group  $R^1$  or  $R^3$  is other than cyano or halo,
- 15 each  $R^2$  and  $R^4$  is independently selected from halo, nitro, lower alkyl optionally substituted by halo, or a group  $R^{14}C(O)O-$  where  $R^{14}$  is optionally substituted hydrocarbyl,
- $n$  is 1 or 2,  $m$  is 0, 1, 2 or 3,  $p$  is 1 or 2 and  $q$  is 0 or 1, provided  $n + m$  does not exceed 4 and  $p + q$  does not exceed 2, and further provided the compounds are other than a
- 20 compound of formula (A) or (B)



(A)

where  $R^{11}$  is a  $C_{1-8}$  alkyl group;

- 25  $R^{12}$  is H, or a  $C_{1-12}$ alkyl or  $C_{2-12}$ alkenyl group, either of which may be optionally substituted by one CN or  $CF_3$  group or one or more halogen atoms; and wherein one or

more  $-\text{CH}_2$ -groups in the alkyl or alkenyl groups is optionally replaced by  $-\text{O}-$ ,  $-\text{S}-$ ,  $-\text{C}(\text{O})-$ ,  $\text{C}(\text{O})\text{O}-$ ,  $-\text{OC}(\text{O})-$  or  $-\text{OC}(\text{O})\text{O}-$  provided that oxygen and sulphur atoms are not directly linked to each other;

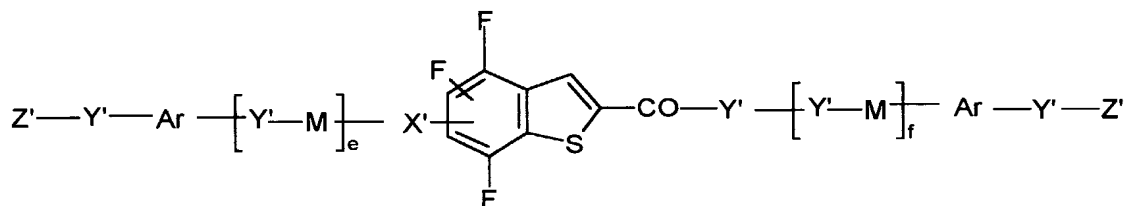
$\text{A}'$  and  $\text{A}''$  are independently selected from:

- 5 a) a trans-1,4-cyclohexylene residue in which one or more non-adjacent  $\text{CH}_2$  groups can be replaced by  $-\text{O}-$  and/or  $-\text{S}-$ ;
- b) a 1,4-cyclohexenyl residue;
- c) a 1,4-phenylene residue in which one or two  $\text{CH}$  groups can be replaced by  $\text{N}$ ;
- d) a residue from the group 1,4-bicyclo(2,2,2)-octylene, piperidine-1,4-diyl,
- 10 naphthalene-2,6-diyl, decahydronaphthalene-2,6-diyl and 1,2,3,4-tetrahydronaphthalene-2,6-diyl;

whereby residues a), b) and c) can be substituted by  $\text{CN}$ ,  $\text{Cl}$ , or  $\text{F}$ ,

$\text{Z}''$  and  $\text{Z}'''$  independently represent  $-\text{C}(\text{O})\text{O}-$ ,  $-\text{OC}(\text{O})-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-\text{CH}_2\text{CH}_2-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{C}\equiv\text{C}-$  or a single bond and

- 15 g is 0, 1 or 2



(B)

20

where

each  $\text{Ar}$  is a bond or a spacer group such as a  $\text{C}_{2-30}$ alkylene or  $\text{C}_{2-30}$ alkenylene group, optionally substituted with  $\text{C}_{1-4}$ alkyl, fluoro, chloro, bromo, cyano, or hydroxy, and optionally interposed with one or more  $-\text{O}-$ ,  $-\text{S}-$ ,  $-\text{NH}-$ ,  $-\text{NR}^c$ ,  $-\text{COO}-$ ,  $\text{OCO}$ ,  $\text{OCOO}$  or

25

$\text{CO}$ ;

each  $\text{M}$  is independently selected from optionally substituted aliphatic, aromatic, heteroaliphatic or a heteroaromatic ring system,

$\text{X}'$  is  $\text{O}$ ,  $\text{S}$ ,  $\text{COO}$ ,  $\text{OCOO}$ ,  $\text{CONH}$  or  $\text{CONR}^c$  where  $\text{R}^c$  is  $\text{C}_{1-4}$ alkyl;

$e$  and  $f$  are independently selected from 0, 1 or 2,

each Y' group is independently selected from O, S, COO, OCO, OCOO, CONH, NHCO, CONR<sup>c</sup>, or NR<sup>c</sup>CO where R<sup>c</sup> is as defined above;  
 each Z' group is independently selected from hydrogen, cyano or a polymerisable group.

5

2. A compound according to claim 1 wherein n is 1, and m is 0 or 1.

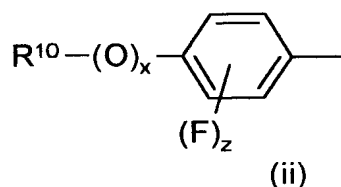
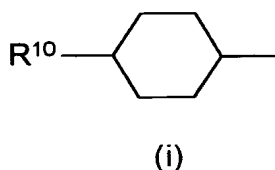
3. A compound according to claim 1 or claim 2 wherein no more than one of the groups R<sup>1</sup> and R<sup>2</sup> is fluoro.

10

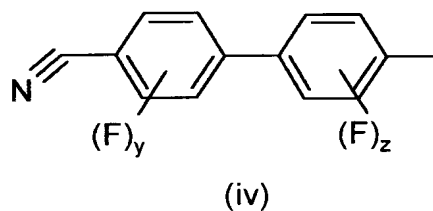
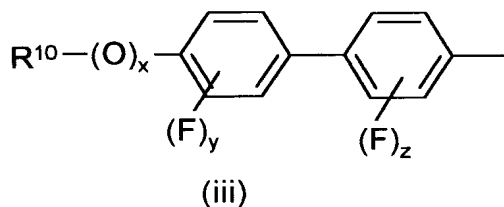
4. A compound according to any one of the preceding claims where one of R<sup>1</sup> or R<sup>3</sup> is cyano or halo and the other is optionally substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or an ester thereof.

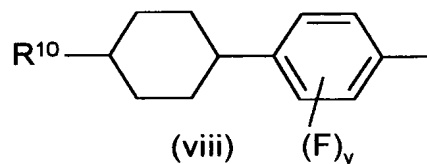
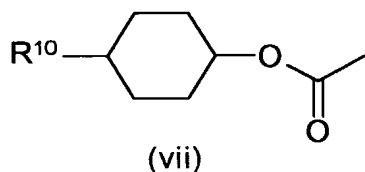
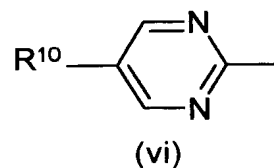
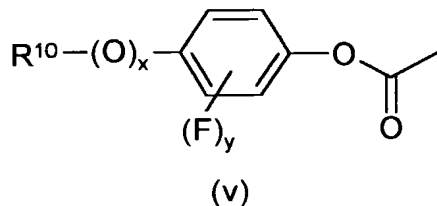
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5. A compound according to any one of the preceding claims wherein R<sup>1</sup> or R<sup>3</sup> where these are other than cyano or halo are selected from groups of formula (i), (ii), (iii), (iv), (v), (vi), (vii) or (viii)



20



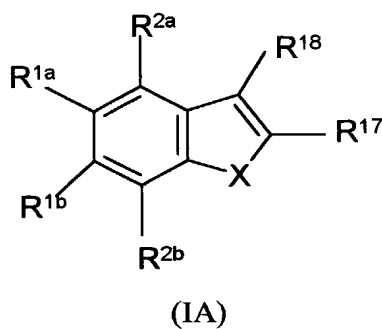


where x is 0 or 1,  $R^{10}$  is an  $C_{1-20}$ alkyl group, and y and z are independently selected from 0, 1 or 2.

5

6. A liquid crystal compound according to claim 1 which is of general formula (IA)

10



where X is oxygen, sulphur or selenium,  $R^{1a}$  and  $R^{1b}$  are independently selected from hydrogen, cyano, halo, optionally substituted hydrocarbyl, optionally substituted heterocyclyl or carboxy or a hydrocarbyl ester or amide thereof, provided that at least one group  $R^{1a}$  or  $R^{1b}$  is other than hydrogen; one of  $R^{17}$  or  $R^{18}$  is cyano, halo, optionally substituted hydrocarbyl, optionally substituted heterocyclyl or carboxy or a hydrocarbyl ester or amide thereof, and the other is hydrogen, halo, nitro, lower alkyl optionally substituted by halo, or a group  $R^{15}C(O)O-$  where  $R^{15}$  is an optionally substituted hydrocarbyl group;  $R^{2a}$  and  $R^{2b}$  are independently selected from hydrogen, halo, nitro, lower alkyl optionally substituted by halo, or a group  $R^{14}C(O)O-$  where  $R^{14}$  is as defined above;

20

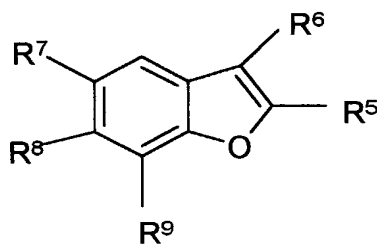
subject to the provisos that:

- (i) at least one group  $R^{1a}$  or  $R^{1b}$  or  $R^{17}$  or  $R^{18}$  is other than cyano or halo;
- (ii) where X is S,  $R^{17}$  is carboxy or a hydrocarbonyl ester or amide thereof,  $R^{18}$  is hydrogen,  $R^{2a}$  and  $R^{2b}$  are not both fluoro;
- 5 (iii) where X is O,  $R^1$  is an optionally substituted hydrocarbonyl or carboxy or a hydrocarbonyl ester or amide thereof,  $R^{2a}$  is hydrogen, and  $R^{1b}$  and  $R^{2b}$  are both fluorine, then  $R^{17}$  is other than  $C_{1-8}$  alkyl.

7. A compound according to claim 6 wherein one of  $R^{1b}$  or  $R^{1a}$  or  $R^{17}$  or  $R^{18}$  in  
 10 formula (IA) is cyano or halo and at least one of the said groups on the other ring of the bicyclic ring of formula (IA) is optionally substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl, optionally substituted alkynyl, an optionally substituted aryl, optionally substituted heterocyclyl, carboxy or a hydrocarbonyl ester thereof.

15

8. A compound according to claim 1 of formula (II)



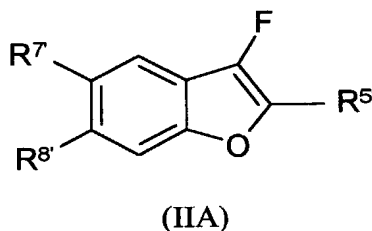
(II)

- 20 wherein  $R^5$  is a group  $R^3$  as defined above in claim 1, one of  $R^7$  and  $R^8$  is a group  $R^1$  as defined in claim 1 and the other is hydrogen or a group  $R^1$  as defined in claim 1;  
 $R^6$  is hydrogen, cyano or fluoro,  
 $R^9$  is hydrogen, cyano or fluoro,  
 provided that where  $R^5$  is cyano or fluoro, at least one of  $R^7$  or  $R^8$  is optionally  
 25 substituted alkyl, optionally substituted cycloalkyl, optionally substituted alkenyl,  
 optionally substituted alkynyl, optionally substituted alkoxy, optionally substituted aryl,  
 optionally substituted heterocyclyl, carboxy or an ester thereof; and where one of  $R^7$  or

$R^8$  is cyano or fluoro and the other is hydrogen,  $R^5$  is optionally substituted alkyl, optionally substituted alkenyl, optionally substituted alkynyl, optionally substituted alkoxy, optionally substituted aryl, optionally substituted heterocyclyl, carboxy or an ester thereof.

5

9. A compound according to claim 8 of formula (IIA)



10 where  $R^{5'}$  is cyano or fluoro, preferably fluoro, one of  $R^{7'}$  and  $R^{8'}$  is hydrogen and the other is an optionally substituted hydrocarbyl group or a heterocyclic group as described above.

10. A compound according to claim 9 wherein at least one of  $R^{7'}$  or  $R^{8'}$  is a group  
15 of sub-formula (i), (ii), (iii), (vi) or (viii) as defined in claim 5.

11. A liquid crystal compound according to any one of claims 1 to 7 where X is oxygen.

20 12. A liquid crystal compound according to claim 8 which comprises a compound of formula (II) where  $R^6$  is hydrogen or fluoro, and  $R^9$  is hydrogen or fluoro.

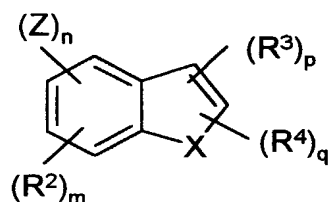
13. A liquid crystal mixture comprising a compound according to any one of the preceding claims.

25

14. A liquid crystal mixture according to claim 13 which comprises at least two different compounds according to any one of claims 1 to 12.

15. A liquid crystal device such as a liquid crystal display device (LCD) comprising a compound according to any one of claims 1 to 12 or a mixture according to claim 13 or claim 14.
- 5 16. A liquid crystal compound according to any one of claims 1 to 12 or a mixture according to claim 13 or claim 14, which has electroclinic properties.
17. An electroclinic device comprising a liquid crystal compound or a mixture according to claim 16.
- 10 18. A liquid crystal compound according to any one of claims 1 to 12 or a mixture according to claim 13 or claim 14, which has cholesteric properties.
- 15 19. A device comprising a liquid crystal compound or a mixture according to claim 18, wherein said device is a thermoptic, thermographic or electro-optical device.
20. A liquid crystal compound according to any one of claims 1 to 12 or a mixture according to claim 13 or claim 14, which has ferroelectric properties.
- 20 21. A ferroelectric device comprising a liquid crystal compound or a mixture according to claim 20.
22. A liquid crystal compound according to any one of claims 1 to 12 or a mixture according to claim 13 or claim 14, which has flexo-electric properties.
- 25 23. A flexo-electric device comprising a liquid crystal compound or a mixture according to claim 22.
24. A liquid crystal compound according to any one of claims 1 to 12 or a mixture according to claim 13 or claim 14, which has pyro-electric properties.
- 30 25. A pyro-electric device comprising a liquid crystal compound or a mixture according to claim 24.

26. A method of preparing a compound of formula (I) according to claim 1 which comprises either (i) reacting a compound of formula (III)



(III)

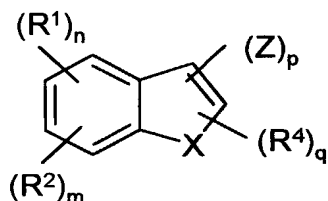
where  $R^2$ ,  $R^3$ ,  $R^4$ ,  $X$ ,  $n$ ,  $m$ ,  $p$  and  $q$  are as defined in claim 1, and  $Z$  is either a leaving group or a group  $B(OH)_2$ , with a compound of formula (IV)



(IV)

where  $R^1$  is as defined in relation to formula (I) and  $Z'$  is a group  $B(OH)_2$  where  $Z$  is a leaving group, or a leaving group where  $Z$  is a group  $B(OH)_2$ ; or

(ii) reacting a compound of formula (V)



(V)

where  $R^1$ ,  $R^2$ ,  $R^4$ ,  $X$ ,  $n$ ,  $m$ ,  $p$  and  $q$  are as defined in relation to formula (I), and  $Z$  is as defined in relation to formula (III), with a compound of formula (VI)

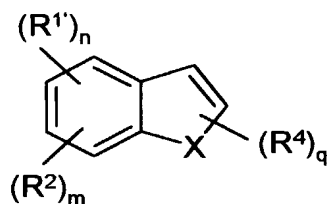


(VI)

where  $R^3$  is as defined in relation to formula (I) and  $Z'$  is as defined in relation to formula (IV), or



(iii) where q is 0 and p is 1 and R<sup>3</sup> is a carboxy group, carboxylating a compound of formula (IX)

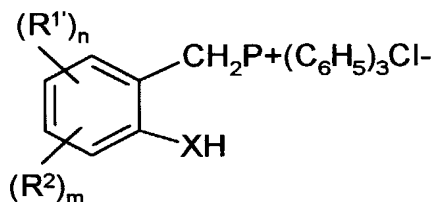


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(IX)

were R<sup>2</sup>, R<sup>4</sup>, X, m, n and q are as defined in relation to formula (I), and R<sup>1'</sup> is a group R<sup>1</sup> as defined in relation to formula (I) or a precursor thereof; with a carboxylating agent, and thereafter acidifying the product with an acid such as glacial acetic acid, or

10 (IV) where q is 0, reacting a compound of formula (XIII)



(XIII)

where R<sup>1'</sup>, R<sup>2</sup>, X, n and m are as defined above, with a compound of formula (XIV)

15



(XIV)

where R<sup>3'</sup> is a group R<sup>3</sup> as defined in relation to formula (I) or a precursor thereof,

20 and thereafter, if necessary, changing any groups R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> to different such groups.

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/03545

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C07D307/78 C07D333/52 C09K19/34

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07D C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

CHEM ABS Data, WPI Data, EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section Ch, Week 199537 Derwent Publications Ltd., London, GB; Class E19, AN 1995-281175 XP002153297 -& JP 07 179856 A (CANON KK), 18 July 1995 (1995-07-18) abstract ---	1,2,5,6, 13,15
X	EP 0 666 262 A (CANON KK) 9 August 1995 (1995-08-09) examples 39,51 ---	1,13,15
X	EP 0 678 509 A (CANON KK) 25 October 1995 (1995-10-25) page 12, line 10 example 3 --- -/--	1,2,13, 15



Further documents are listed in the continuation of box C.



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European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
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